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Assessment of the southern Gulf of St. Lawrence (NAFO Division 4T) stock of American plaice (*Hippoglossoides platessoides*), March 2016

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

While the American plaice stock in Division 4T of the Northwest Atlantic Fisheries Organization was historically the most important flatfish fishery in the southern Gulf of St. Lawrence, it is now at low levels with little to no prospect of rebuilding to healthy levels in the next 5 years. The stock was assessed using a Virtual Population Analysis that estimated time-varying natural mortality. The current spawning stock biomass of the stock was estimated to be 55,023 t, which is 40% of the limit reference point of 139,134 t. Under current productivity conditions the spawning stock biomass is expected to decrease over the next 5 years under TACs of 0 t, 100 t or 250 t. The lack of rebuilding prospects stems from the elevated level of natural mortality experienced by the population.

Évaluation de la plie canadienne (*Hippoglossoides platessoides*) du sud du golfe du Saint-Laurent (division 4T de l'OPANO), mars 2018

RÉSUMÉ

Malgré qu'il ait supporté la plus importante pêche de poissons plats dans le Golfe du Saint-Laurent, le stock de plie canadienne de la division 4T de l'OPANO est maintenant à un niveau historiquement bas et n'a pratiquement aucune chance de se rétablir dans les 5 prochaines années. Le stock a été évalué à l'aide d'un modèle virtuel structuré par âge qui estime l'évolution temporelle de la mortalité naturelle. La biomasse du stock reproducteur est présentement estimée à 55 023 t, ce qui représente 40 % du point de référence limite de 139 134 t. Sous des conditions de productivités actuelles on s'attend à ce que la biomasse du stock reproducteur diminue au cours des 5 prochaines années sous un TAC de 0 t, 100 t ou 200 t. Les perspectives de reconstitution sont faibles dû aux niveaux élevés de mortalité naturelle subis par la population.

INTRODUCTION

American plaice (*Hippoglossoides platessoides*) is a righteye flounder whose distribution spans the North Atlantic Ocean. The species is split into two subspecies: *Hippoglossoides platessoides platessoides* Fabricius 1780 (American plaice) from the northwest Atlantic and *Hippoglossoides platessoides limandoides* Bloch 1788 (long rough dab) from the northeast Atlantic (Kuklinski 2004). In the northwest Atlantic, the species ranges from 60°N in the United States to above the Arctic Circle in Canadian waters, the species is divided in a number of different stocks and the current assessment is for the southern Gulf of St. Lawrence stock (NAFO Div. 4T, hereafter referred to as 4T).

American plaice in the southern Gulf of St. Lawrence was once an abundant resource and supported an extensive commercial fishery. In the 1980s, it was the most important commercial flatfish fishery in the Gulf of St. Lawrence. The resource then declined substantially during the 1990s and now supports a very modest fishery.

Early attempts at assessing the stock with a population model were unsuccessful because of the unreliability of the catch data (Landry 1998; Tallman and Snider 1998; Tallman and Snider 1999). This unreliability was related to a high rate of at-sea discarding of small plaice (Tallman 1991). A sequential population analysis was eventually evaluated to assess the stock (Tallman and Power-Cleland 1999) but was not deemed scientifically appropriate by the committee reviewing the assessment. The first assessment that used a population model was in 2005, but it only assessed the population status back to 1963 because of the substantial at-sea discards which took place in the 1970s and 1980s (Morin et al. 2006). The population model assumed that natural mortality was constant over time since 1963.

Improvements were subsequently made to the analytical framework to make it scientifically suitable for the assessment of the stock over a longer time period. Changes included the estimation of the 1970s and 1980s at-sea discards (Tallman 1991) and the estimation of time trends in natural mortality. The last assessment of the stock (in 2012) used an age-structured approach and was implemented as a virtual Population Analysis (VPA) to estimate the temporal trends in abundance, biomass and natural and fishing mortalities (Morin and Lefebvre 2012) and to define reference points for the stock (Morin et al. 2012).

Because of the low state of the resource, the Committee for the Status of Endangered Wildlife in Canada (COSEWIC) assessed the Designatable Unit (DU) called the Cavendish-Bird Rocks Population of American plaice and determined its status as "threatened". The 4T plaice stock was a component of this DU. A Recovery Potential Assessment (RPA) was conducted in order to inform stakeholders and management authorities of the future prospects of the three different American plaice stocks in this DU, including the southern Gulf stock (DFO 2011). The findings of the RPA for the NAFO 4T stock were that the population would continue to decline even if the fishing mortality was reduced to zero (i.e., if the stock was not fished).

In order to further guide management and conservation measures, a biomass limit reference point was developed for the stock (Morin et al. 2012). The southern Gulf stock was estimated to be highly depleted, with the spawning stock biomass below the limit reference point for 16 of the last 19 years considered.

The assessment described herein was presented at a Regional Advisory Process meeting in March 2016. The present document updates the stock assessment for the year 2016, using data up to 2015.

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$$[illegible] \tag{2}$$

[illegible]

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patterns in decadal growth indicate that the asymptotic length of both males and females decreased from the 1970s to the 1990s and has since stabilised at a much smaller length than at the earliest data collection period.

The paired observations of length and age collected during the annual trawl survey were used to generate the weight-at-age matrix used in the population model. Because the survey takes place in September of each year but the population model keeps track of the number of individuals on January 1st of each year, the average weight-at-age estimated from the survey data was adjusted accordingly. The weight-at-age matrix allows the population numbers to be converted into population biomass. The beginning of the year weight-at-age matrix used in the population model can be found on Table 5 and the temporal trends in weight-at-age for ages 6, 8, 10, and 12 can be found in Figure 16.

Maturation

The annual proportion of mature plaice since 1997 was obtained from logistic regressions applied to proportions of mature male and female plaice sampled in the RV survey (Table 6). The maturity stages for surveys before 1997 are currently undergoing review as they might be unreliable. Therefore, we applied the median values of coefficients of logistic ogives of maturity since 1997 to the period 1970-1996. Maturity coding in recent years was also problematic, leading to unreliable information for years 2013 to 2015. For this reason, the proportions mature-at-age for years 2012 to 2015 were set to those in 2012.

OTHER SOURCES OF DATA CONSIDERED

SENTINEL SURVEY DATA

An additional survey that is available to calibrate the population dynamics model started in 1994 in order to obtain an industry-based abundance index for Atlantic cod following the closure of the fishery in 1993 (Chouinard et al. 1998). The mobile gear sentinel survey (MS) was revised in 2003 and adopted the same stratified random sampling design that is used in the annual September ecosystem survey. The survey is conducted by a number of commercial vessels and is thoroughly described in Savoie (2012). The population biomass index derived from the mobile sentinel survey can be found on Figure 17. The index shows a steadily decline since 2003 with some minor increases in 2004, 2011 and 2012. It has since stabilised to its lowest level over the last three years. For the 2003 to 2015 period, the rate of decline of the MS index is more pronounced than the RV index.

The MS catch-at-age matrix used in the model fitting can be found in Table 4. The catch-at-age matrix for this survey was generated with the same procedure as for the RV survey catch-at-age matrix. The length composition was derived from sampling in the sentinel survey, but the conversion to age composition was based on annual age-length keys in corresponding RV surveys.

POPULATION DYNAMICS MODEL

The NAFO 4T American plaice stock has been under scientific scrutiny since the 1980s. The stock was initially assessed qualitatively since there were a number of problematic aspects in the available data. The current assessment uses an age-structured population model to estimate the temporal trends in stock abundance and biomass, to estimate a lower limit reference point and to forecast the stock trajectories under different management options.

VIRTUAL POPULATION ANALYSIS (VPA)

Methods

As in previous assessments, we use a virtual population analysis (VPA) framework (Hilborn and Walters 1992) as an assessment model for the 4T American plaice stock.

The information that feeds into the virtual population analysis consists of the following:

- Commercial catch-at-age matrix, including estimated at-sea discards (Table 2),
- Beginning of the year weight-at-age matrix (Table 5),
- Proportion mature-at-age matrix (Table 6),
- RV catch-at-age matrix (Table 3), and
- Sentinel survey catch-at-age matrix (Table 4).

A number of different model formulations were evaluated during the assessment but only the most suitable version was used for the provision of scientific advice presented here. The model features, including the parameters to be estimated are as follows:

- Ages modelled: 4 to 16+ (13 age classes)
- Years considered: 1976 to 2015 (40 years)
- Estimated number of parameters: 144
    - Age-specific abundance in the last year of the model: 12 parameters
    - Yearly natural mortality in two age groups (4-9 years and 10+ years) estimated as a random walk: 80 parameters
    - RV catchability-at-age: 13 parameters
    - MS catchability-at-age: 13 parameters
    - Age-specific observation error variance for the RV survey: 13 parameters
    - Age-specific observation error variance for the MS survey: 13 parameters.

Independent time series of the instantaneous natural mortality (M) were estimated for ages 4-9 ($j = 1$) and ages 10+ ($j = 2$) as random walks:

$$M_{j,1} = M_{ini_j}$$

$$M_{j,y} = M_{j,y-1} e^{Mdev_{j,y}} \quad (3)$$

where M_{ini_j} is M in year 1 (1976). M_{ini_j} and $Mdev_{j,y}$ are parameters estimated by the model. The Mdev parameters were assumed to be normally distributed with a mean of 0 and a standard deviation set at 0.075. Priors were supplied for M_{ini_j}. These priors were normally distributed with means of 0.6 and 0.3 for American plaice aged 4-9 and 10+.

In the VPA model that was used, parameters were estimated by minimizing an objective function with the following components:

- a component for the discrepancy between observed and predicted values of the abundance indices at age, which were assumed to be log-normally distributed,
- a normal prior for the log M deviations, and

- a normal prior for the initial values of *M*.

All data analyses were conducted using the R language and environment for statistical computing (R Core Team, 2015) and the population dynamics model was implemented in AD Model Builder (Fournier et al. 2012).

Results

The model estimated age-specific abundance and its corresponding survey-derived estimates (corrected for survey catchability) can be found on Figure 18. The VPA estimates of age-specific abundance provide a good fit to both survey indices and indicate significant declines in the abundance of American plaice in the southern Gulf of St. Lawrence.

The residuals for the RV survey (Fig. 19) indicate that the model had a systematic overestimation of the abundance of individuals aged 11 and older in the late 1970s and early 1980s and an underestimation of the same age classes since the mid-2000s. Strong year classes born in 1994, 1999 and 2000 are also underestimated by the population model and appear as oblique series of solid dots in Figure 19. The residuals of the MS survey show that the population model underestimated the abundance of all ages in the first few years of the MS survey and overestimated the abundance of all ages in the last 3 years (Fig. 20). This was caused by the fact that in recent years the MS index declined faster than the RV index, and the fact that the population model will preferentially fit the RV survey indices because they span a longer time period.

The model estimate of the instantaneous rates of natural and fishing mortality for ages 4-9 and ages 10+ can be found on Figure 21. Natural mortality has been higher than fishing mortality for the entire time period of the assessment. Fishing mortality of individuals aged 10 and older peaked in 1991 and has decreased to a negligible level for the last 10 years. Natural mortality of individuals aged 4 to 9 is currently estimated to be lower than at earlier times while it has steadily increased to an elevated level for individuals aged 10 and older.

Retrospective analysis of the population model, showing the resulting estimates in spawning stock biomass, recruitment, natural mortality and fishing mortality obtained after removing one to five years of data can be found on Figure 22. The model had an important retrospective pattern in the estimates of natural mortality for American plaice age 10+ in the recent period, and a retrospective pattern in natural mortality of the 4-9 years age group over the entire time series. This produces large differences in the revised values of SSB, recruitment, and mortality rates through time.

Model estimates are obtained by running a Monte Carlo Markov Chain (MCMC) simulation on the fitted population model. The MCMC run consisted of 201,000 iterations with a burn-in period of 1,000 iterations and each 40 iterations was saved after the burn-in period, for a total of 5,000 MCMC estimates. The median value from the MCMC runs are used as the reported model estimates for model parameters, population abundance, population biomass, natural mortality and fishing mortality.

The estimated spawning stock biomass at the beginning of 2015 (the MCMC median) was 55,023 t. Since the last assessment in 2012 the spawning stock biomass has increased marginally (Fig. 23).

REFERENCE POINTS

Earlier attempts at establishing reference points defined a lower limit spawning stock biomass that represented the level where recruitment was half of the maximum level (Morin et al. 2012) .

The limit reference point (LRP) was re-estimated using the results of the new population dynamics model. We used the estimated spawning stock biomass (SSB) and recruitment (R) time-series (Fig. 24) to fit a Beverton-Holt stock-recruitment model. The recruitment time-series was matched with the spawning stock biomass that produced it (i.e., offset by a recruitment age of four years) and the following model was fitted to the available data:

$$R \sim Lognormal(\mu_t, \varepsilon)$$

$$\mu_t = log\left(\frac{\alpha SSB_t}{\beta + SSB_t}\right)$$

$$\varepsilon \sim N(0, \sigma^2) \qquad (4)$$

where, α and β are the estimated parameters, and β represents the spawning stock biomass that yields half of the maximum recruitment, which was suggested as a limit reference point (Myers et al. 1994). The estimated LRP for American plaice in NAFO Div. 4T is 139,135 t (SE = 76,970 t) and the 2015 spawning stock biomass of 55,023 t is 40% of the LRP indicating that the stock is currently in the critical zone (Fig. 23 and Fig. 24). The 95th percentile of the estimated SSB from the population model has been below the LRP and the stock has been in the critical zone since 1993.

STOCK PROJECTIONS AND MANAGEMENT ADVICE

The fitted population models were used to predict the temporal evolution of the stock under different management options. We evaluated three 5-year stock projection scenarios:

- no catch (TAC of 0 t),
- a TAC of 100 t, and
- a TAC of 250 t.

Despite the almost insignificant level of fishing mortality experienced by the stock, its rebuilding prospects under current conditions are low because of the high level of natural mortality. Under current conditions, the SSB is expected to remain in the critical zone (with > 95% chance of being below B_{lim}) during 2016 to 2021 at all annual TAC options (Fig. 25).

STOCK STATUS INDICATORS

The NAFO 4T American plaice stock is currently assessed and managed on a five-year cycle. Indicators are needed to characterise stock status in years between assessments. The indicators suggested are the biomass indices obtained from the RV survey. These indices can have significant observation error and changes in stock biomass should not be inferred from annual estimates. Moving averages are therefore suggested, with a three-year moving average recommended for tracking American plaice stock biomass. Important changes in the indicator, e.g., a large change in the moving average from its value in the last assessment year would trigger a re-assessment before the five-year period has elapsed. Currently, the TAC for this stock is set to 250 t but has not exceeded 40 t for the last three years.

In order to implement this approach it is necessary to relate the LRP from its population scale in January to the scale of the RV index in September. This is done by scaling the biomass over the whole stock area to the scale of the RV index, which is either in trawlable biomass or in biomass per tow. Since the LRP is in spawning stock biomass units, a regression between the commercial size catch biomass (individuals ≥ 30cm) and the VPA-derived SSB estimates was used to relate the two variables. The slope of the regression was then used to convert the LRP

estimate into its equivalent RV index in biomass per tow or in trawlable biomass. The resulting scaled LRP is 19.5 kg/tow or 33,770 t of trawlable biomass.

The three-year moving average will be computed annually for the next five years and an assessment will be triggered if its value increases beyond the scaled LRP or if its decline exceeds those predicted under a TAC of 250t.

CONCLUSIONS

The prospect for the rebuilding of the NAFO Div. 4T American plaice to a healthy level remains grim. The low levels of directed fishery catches of this stock and the small amount of bycatch in other fisheries are positive situations for rebuilding, but the high natural mortality experienced by this stock is hampering its recovery. A likely reason for the increased natural mortality is predation by grey seals (Swain and Benoît 2015).

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TABLES

Table 1. Yearly landings (tonnes) of American plaice in NAFO Division 4T by major gear type. Gear codes: OTB = unspecified otter trawls, OTB1 = side otter trawls, OTB2 = stern otter trawls SNU =seines, PTB =pair trawls, GNS =gillnets, LLS = longlines, LH =handlines, TAC = total allowable catch. Note that the 2015 landings data are preliminary. The numbers in parentheses represent the landings for "unspecified flounder".

Year	OTB	OTB1	OTB2	SNU	PTB	GNS	LLS	LH	OTHER	TOTAL	TAC
1960	6130 (1794)	0 (0)	0 (0)	1557 (516)	0 (0)	0 (0)	218 (73)	3 (0)	73 (22)	7981 (2405)	na
1961	4492 (1591)	0 (0)	0 (0)	1988 (708)	0 (0)	23 (8)	22 (8)	450 (158)	43 (20)	7018 (2493)	na
1962	2784 (878)	0 (0)	0 (0)	1294 (422)	0 (0)	0 (0)	49 (4)	465 (0)	0 (0)	4592 (1304)	na
1963	5007 (0)	0 (0)	0 (0)	1954 (0)	0 (0)	174 (0)	32 (0)	2 (0)	527 (0)	7696 (0)	na
1964	5724 (0)	0 (0)	0 (0)	1507 (0)	0 (0)	0 (0)	3 (0)	0 (0)	602 (0)	7836 (0)	na
1965	7782 (0)	0 (0)	0 (0)	1854 (0)	0 (0)	388 (0)	212 (0)	0 (0)	149 (0)	10385 (0)	na
1966	0 (0)	8066 (0)	581 (0)	2322 (0)	0 (0)	375 (0)	2 (0)	0 (0)	434 (0)	11780 (0)	na
1967	0 (0)	7237 (0)	211 (0)	1151 (0)	0 (0)	326 (0)	117 (0)	50 (0)	259 (0)	9351 (0)	na
1968	0 (0)	7900 (0)	237 (0)	911 (0)	0 (0)	298 (0)	4 (0)	36 (0)	182 (0)	9568 (0)	na
1969	0 (0)	5609 (0)	425 (0)	1418 (0)	0 (0)	421 (0)	58 (0)	17 (0)	244 (0)	8192 (0)	na
1970	29 (0)	5793 (0)	477 (0)	2241 (0)	0 (0)	439 (0)	79 (0)	7 (0)	136 (0)	9201 (0)	na
1971	0 (0)	4996 (0)	409 (0)	2884 (0)	0 (0)	876 (0)	21 (0)	9 (0)	318 (0)	9513 (0)	na
1972	14 (10)	4275 (595)	860 (3)	2576 (0)	0 (0)	286 (520)	73 (42)	11 (30)	199 (1)	8294 (1201)	na
1973	20 (0)	3087 (1091)	471 (0)	2744 (0)	0 (0)	241 (232)	73 (6)	1 (34)	268 (25)	6905 (1388)	na
1974	0 (0)	3556 (160)	585 (0)	3719 (0)	0 (0)	250 (375)	6 (6)	5 (6)	364 (55)	8485 (602)	na
1975	10 (32)	3207 (1628)	795 (0)	3897 (0)	0 (0)	217 (757)	14 (19)	0 (1)	303 (27)	8443 (2464)	na
1976	41 (1)	4098 (301)	2864 (0)	3395 (4)	0 (0)	225 (346)	2 (0)	6 (3)	562 (13)	11193 (668)	na
1977	35 (2)	4261 (121)	375 (0)	4013 (6)	0 (0)	242 (1013)	16 (0)	17 (1)	271 (20)	9230 (1163)	10000
1978	58 (0)	3651 (72)	889 (3)	3495 (19)	0 (0)	379 (601)	42 (0)	38 (0)	479 (69)	9031 (764)	10000
1979	83 (0)	3415 (91)	961 (4)	3719 (37)	0 (0)	721 (690)	9 (0)	17 (2)	1071 (17)	9996 (841)	10000
1980	1485 (0)	1809 (25)	558 (40)	3500 (78)	0 (0)	717 (0)	62 (0)	5 (0)	156 (616)	8292 (759)	10000
1981	1022 (0)	1311 (34)	290 (35)	3570 (49)	0 (0)	1084 (0)	98 (0)	2 (0)	457 (0)	7834 (118)	10000
1982	742 (10)	580 (60)	137 (1)	4124 (1)	0 (0)	805 (1)	94 (0)	5 (0)	55 (271)	6542 (344)	10000
1983	821 (0)	479 (0)	102 (0)	4095 (1)	0 (0)	494 (0)	76 (0)	10 (0)	17 (791)	6094 (792)	10000
1984	239 (0)	601 (14)	2582 (2)	3702 (13)	0 (0)	1905 (14)	386 (3)	25 (0)	159 (0)	9699 (46)	10000
1985	165 (0)	824 (0)	3027 (0)	3870 (0)	83 (0)	1007 (3)	404 (0)	29 (0)	81 (0)	9490 (3)	10000
1986	74 (0)	768 (0)	2125 (0)	3289 (0)	105 (0)	663 (0)	318 (0)	44 (0)	22 (0)	7408 (0)	10000
1987	50 (0)	1075 (0)	2101 (0)	3140 (0)	123 (0)	831 (0)	664 (0)	67 (0)	13 (0)	8064 (0)	10000
1988	84 (0)	540 (0)	2002 (0)	2842 (0)	0 (0)	957 (0)	484 (0)	33 (0)	47 (0)	6989 (0)	10000
1989	14 (0)	495 (0)	1602 (2)	2489 (30)	0 (0)	501 (0)	212 (0)	386 (0)	18 (4)	5717 (36)	10000
1990	9 (0)	677 (0)	1205 (0)	2259 (12)	4 (0)	474 (25)	240 (0)	26 (0)	13 (0)	4907 (37)	10000
1991	22 (0)	146 (0)	1232 (11)	3057 (2)	94 (0)	525 (18)	102 (6)	22 (0)	22 (0)	5222 (37)	10000
1992	19 (0)	175 (0)	1405 (9)	2793 (8)	174 (0)	537 (70)	70 (4)	14 (0)	11 (0)	5198 (91)	10000
1993	0 (0)	77 (0)	149 (9)	928 (0)	63 (0)	592 (1)	28 (2)	1 (0)	15 (0)	1853 (12)	5000
1994	1 (0)	4 (0)	274 (0)	1761 (15)	90 (0)	243 (0)	13 (0)	0 (0)	34 (0)	2420 (15)	5000
1995	0 (0)	1 (0)	347 (1)	1752 (4)	123 (0)	136 (0)	2 (0)	0 (0)	33 (0)	2394 (5)	5000

Table 3. Estimated numbers caught at age (thousands) of 47 [illegible] plaice (landings + estimated discarded catch at age)

Year	Age												Total
	0	1	2	3	4	5	6	7	8	9	10	11+	
1970	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1971	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1972	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1973	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1974	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1975	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1976	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1977	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1978	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1979	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1980	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1981	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1982	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1983	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1984	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1985	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1986	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1987	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1988	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1989	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1990	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1991	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1992	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1993	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1994	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1995	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1996	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1997	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1998	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1999	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2001	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2002	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2003	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2004	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2005	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2006	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2007	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2008	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2009	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2010	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2011	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2012	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2013	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2014	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2015	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 6. Mean standardized catch at age (thousands) of American plaice from the annual southern Gulf of St. Lawrence sentinel survey.

	Age												
Year	4	5	6	7	8	9	10	11	12	13	14	15	16+
2004	4972	11640	7990	10980	4380	3810	7110	4387	2480	2328	1781	1442	574
2005	4972	11280	8460	11681	5535	10324	7428	4403	2838	2468	1918	1483	594
2006	4981	11817	10748	1337	6111	4103	6298	2822	2011	1284	943	368	519
2007	4774	9248	10775	13833	6338	4531	5948	3187	2023	1187	813	474	385
2008	5028	9940	8389	8674	6281	5275	5511	2677	1483	1310	922	479	457
2009	5368	9969	8407	9969	11889	6508	2868	2719	1389	991	941	281	785
2009	5363	9529	9780	7373	5835	7838	6740	1822	1558	1024	807	254	339
2010	5749	9356	9194	9539	4889	2991	4883	2597	1247	1087	830	372	624
2011	5710	8274	9382	8381	4804	5139	4522	3138	1552	1003	588	398	383
2012	5726	9108	11655	8558	5312	4418	5346	4834	3882	1859	913	551	588
2013	5963	10491	2799	9803	5799	1973	1452	1249	858	640	438	237	143
2014	5368	9100	9678	5191	1848	807	467	345	291	267	139	94	66
2015	992	1852	2813	1951	1804	881	873	459	384	272	137	67	83

Table 5. Mean weight-at-age (kg) of American plaice from the annual southern Gulf of St. Lawrence research vessel trawl survey.

	Age												
Year	4	5	6	7	8	9	10	11	12	13	14	15	16+
1976	0.047	0.081	0.131	0.197	0.257	0.306	0.337	0.446	0.518	0.759	0.733	0.895	1.656
1977	0.048	0.077	0.120	0.179	0.250	0.312	0.379	0.440	0.572	0.716	0.906	1.004	1.500
1978	0.039	0.071	0.100	0.147	0.212	0.301	0.357	0.466	0.566	0.671	0.944	0.960	1.544
1979	0.038	0.057	0.091	0.119	0.170	0.240	0.316	0.399	0.492	0.644	0.774	1.114	1.445
1980	0.053	0.066	0.089	0.129	0.172	0.233	0.312	0.403	0.522	0.604	0.802	1.000	1.451
1981	0.060	0.086	0.113	0.136	0.184	0.237	0.308	0.390	0.549	0.671	0.801	0.879	1.264
1982	0.064	0.095	0.119	0.144	0.169	0.220	0.279	0.366	0.508	0.659	0.812	0.903	1.194
1983	0.056	0.084	0.120	0.139	0.152	0.185	0.230	0.292	0.379	0.596	0.732	0.846	1.169
1984	0.056	0.083	0.108	0.135	0.153	0.172	0.201	0.246	0.302	0.385	0.590	0.753	1.190
1985	0.059	0.095	0.117	0.146	0.173	0.189	0.217	0.240	0.285	0.338	0.448	0.556	1.153
1986	0.062	0.094	0.132	0.160	0.191	0.213	0.245	0.256	0.268	0.294	0.337	0.413	0.729
1987	0.057	0.097	0.131	0.161	0.193	0.212	0.240	0.282	0.303	0.353	0.365	0.376	0.748
1988	0.045	0.082	0.119	0.154	0.182	0.215	0.227	0.268	0.293	0.344	0.417	0.515	0.865
1989	0.047	0.083	0.120	0.161	0.187	0.228	0.249	0.271	0.303	0.325	0.376	0.446	0.892
1990	0.055	0.092	0.129	0.169	0.209	0.228	0.270	0.285	0.333	0.357	0.416	0.465	0.871
1991	0.060	0.101	0.140	0.178	0.216	0.244	0.262	0.293	0.303	0.347	0.360	0.424	0.718
1992	0.066	0.105	0.143	0.178	0.211	0.238	0.269	0.287	0.318	0.332	0.339	0.379	0.541
1993	0.053	0.094	0.131	0.166	0.201	0.231	0.268	0.297	0.310	0.356	0.385	0.453	0.704
1994	0.053	0.086	0.128	0.165	0.200	0.227	0.255	0.299	0.312	0.334	0.385	0.442	0.627
1995	0.052	0.088	0.119	0.158	0.189	0.224	0.254	0.274	0.298	0.333	0.382	0.447	0.581
1996	0.051	0.080	0.119	0.150	0.189	0.218	0.245	0.280	0.296	0.327	0.384	0.431	0.600
1997	0.047	0.084	0.114	0.150	0.185	0.223	0.251	0.274	0.296	0.296	0.381	0.418	0.544
1998	0.041	0.075	0.112	0.147	0.182	0.218	0.247	0.270	0.307	0.329	0.351	0.377	0.607
1999	0.047	0.076	0.118	0.154	0.188	0.226	0.255	0.281	0.322	0.384	0.418	0.488	0.563
2000	0.053	0.086	0.119	0.167	0.197	0.228	0.253	0.275	0.329	0.396	0.486	0.528	0.666
2001	0.060	0.087	0.120	0.146	0.184	0.207	0.240	0.251	0.280	0.327	0.398	0.488	0.605
2002	0.046	0.088	0.118	0.150	0.170	0.198	0.228	0.261	0.270	0.319	0.359	0.405	0.491
2003	0.044	0.080	0.118	0.149	0.174	0.198	0.227	0.258	0.269	0.310	0.350	0.398	0.000
2004	0.042	0.073	0.118	0.149	0.179	0.198	0.226	0.254	0.268	0.302	0.341	0.390	0.443
2005	0.051	0.077	0.114	0.151	0.182	0.204	0.214	0.252	0.262	0.273	0.303	0.352	0.448
2006	0.052	0.084	0.108	0.143	0.170	0.198	0.223	0.225	0.255	0.282	0.298	0.340	0.462
2007	0.054	0.082	0.115	0.134	0.166	0.194	0.213	0.235	0.241	0.272	0.300	0.319	0.469
2008	0.055	0.080	0.107	0.134	0.157	0.192	0.209	0.235	0.259	0.256	0.320	0.307	0.412
2009	0.036	0.079	0.104	0.130	0.146	0.176	0.213	0.224	0.249	0.259	0.278	0.327	0.337
2010	0.046	0.071	0.106	0.126	0.151	0.164	0.186	0.217	0.224	0.248	0.253	0.281	0.332
2011	0.043	0.076	0.098	0.130	0.146	0.164	0.185	0.205	0.236	0.231	0.273	0.281	0.346
2012	0.037	0.064	0.095	0.118	0.148	0.161	0.181	0.191	0.233	0.260	0.253	0.284	0.329
2013	0.035	0.059	0.088	0.120	0.143	0.166	0.170	0.198	0.212	0.250	0.280	0.277	0.346
2014	0.043	0.073	0.104	0.131	0.152	0.184	0.215	0.209	0.236	0.276	0.293	0.342	0.469
2015	0.049	0.086	0.118	0.147	0.171	0.185	0.209	0.249	0.242	0.262	0.306	0.318	0.427

Table 6. Proportion American plaice mature-at-age in the annual southern Gulf of St. Lawrence research vessel trawl survey.

	Age												
Year	4	5	6	7	8	9	10	11	12	13	14	15	16+
1976	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1977	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.995
1978	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.995
1979	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1980	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.993
1981	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1982	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1983	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1984	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.995
1985	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.995
1986	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.993
1987	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.995
1988	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1989	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1990	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.993
1991	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1992	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.993
1993	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.995
1994	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1995	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.994
1996	0.350	0.455	0.564	0.667	0.756	0.828	0.881	0.920	0.947	0.965	0.977	0.985	0.993
1997	0.280	0.360	0.430	0.510	0.590	0.670	0.740	0.790	0.840	0.880	0.910	0.930	0.963
1998	0.210	0.350	0.520	0.690	0.820	0.900	0.950	0.980	0.990	0.990	1.000	1.000	1.000
1999	0.290	0.420	0.560	0.690	0.790	0.870	0.920	0.950	0.970	0.980	0.990	0.990	1.000
2000	0.290	0.400	0.520	0.640	0.740	0.820	0.880	0.920	0.950	0.970	0.980	0.990	0.996
2001	0.260	0.320	0.390	0.460	0.530	0.600	0.670	0.730	0.780	0.820	0.860	0.890	0.936
2002	0.170	0.280	0.430	0.590	0.730	0.840	0.910	0.950	0.970	0.990	0.990	1.000	1.000
2003	0.285	0.410	0.550	0.685	0.795	0.880	0.930	0.960	0.975	0.990	0.990	1.000	1.000
2004	0.400	0.540	0.670	0.780	0.860	0.920	0.950	0.970	0.980	0.990	0.990	1.000	1.000
2005	0.280	0.380	0.480	0.590	0.690	0.770	0.840	0.890	0.920	0.950	0.970	0.980	0.991
2006	0.350	0.460	0.570	0.680	0.770	0.840	0.890	0.930	0.950	0.970	0.980	0.990	0.993
2007	0.440	0.580	0.710	0.810	0.880	0.930	0.960	0.980	0.990	0.990	1.000	1.000	1.000
2008	0.273	0.375	0.489	0.604	0.709	0.795	0.861	0.908	0.941	0.962	0.976	0.985	0.993
2009	0.285	0.372	0.467	0.566	0.659	0.741	0.809	0.863	0.903	0.933	0.954	0.968	0.984
2010	0.366	0.556	0.731	0.855	0.928	0.965	0.984	0.992	0.997	0.998	0.999	1.000	1.000
2011	0.213	0.349	0.515	0.678	0.807	0.892	0.943	0.970	0.985	0.992	0.996	0.998	0.999
2012	0.288	0.426	0.571	0.700	0.798	0.866	0.912	0.942	0.962	0.974	0.983	0.989	0.994
2013	0.288	0.426	0.571	0.700	0.798	0.866	0.912	0.942	0.962	0.974	0.983	0.989	0.994
2014	0.288	0.426	0.571	0.700	0.798	0.866	0.912	0.942	0.962	0.974	0.983	0.989	0.994
2015	0.288	0.426	0.571	0.700	0.798	0.866	0.912	0.942	0.962	0.974	0.983	0.989	0.994

Table 7. Age-specific yearly population size estimated from the virtual population analysis. Numbers are in thousand individuals and represent the population size on January 1st.

Year	Age												
	4	5	6	7	8	9	10	11	12	13	14	15	16+
1976	5506740	2652220	1173090	438765	158842	82742	48060	37834	18471	15033	4031	3766	13820
1977	5687200	2792990	1338690	581774	213077	75131	37410	32978	26712	11480	10357	2424	11642
1978	4750390	2660780	1303550	618819	260612	92934	31787	26477	24003	18991	8319	7532	9870
1979	3566170	2085690	1166900	568955	265090	108239	38330	22161	18601	17685	13799	5797	12622
1980	2068020	1534650	896789	499774	239743	107079	41333	26148	15155	13237	13016	9904	13575
1981	1546980	894092	662534	385075	211779	98677	42555	29682	18600	9854	8859	9108	16922
1982	995381	689958	398520	294700	170352	92613	42212	31591	21772	13450	6936	6300	17442
1983	887602	465655	322496	185985	136851	77568	41168	30300	23148	15834	9653	4745	17284
1984	898374	444016	232678	160800	92418	67475	37479	30441	21969	16405	11029	6846	14871
1985	767836	482793	238247	124277	85133	48265	34558	26088	21390	15255	11766	7541	14518
1986	1109410	436093	273695	134627	69625	46928	26059	24623	17377	13552	9802	7540	14245
1987	942724	647212	254148	158708	77369	39141	26019	18506	17240	11461	8721	6356	14394
1988	1213250	547233	374983	145865	89495	42296	20558	17034	11839	10756	6951	4902	12715
1989	1502750	687350	309647	211212	81449	48923	22300	14043	11468	7522	6825	4181	10590
1990	1552230	831825	379858	170201	114478	42861	24799	14084	8844	7229	4616	4271	9089
1991	1353110	839314	448943	203892	90359	59370	21574	15452	8558	5362	4314	2798	8074
1992	1853330	707240	436983	231237	102177	43513	26472	10877	7596	3774	2481	2021	4911
1993	1184940	945024	359621	220428	114860	48979	20184	13452	5112	3568	1782	1090	3239
1994	626644	602383	479663	181381	110263	56513	23641	10800	6866	2486	1831	920	2248
1995	614909	321048	308410	245023	92085	55746	28355	12556	5649	3491	1214	918	1551
1996	732099	315279	164574	157888	125018	46527	27906	14766	6317	2721	1584	512	1000
1997	531849	373713	160894	83848	80181	63412	23414	14827	7766	3255	1346	741	691
1998	1256420	270496	190046	81693	42378	40242	31626	12416	7825	3974	1624	628	632
1999	378876	634185	136480	95833	40926	21074	19945	17969	7019	4338	2176	877	609
2000	433112	196141	328306	70432	49362	20559	10377	11336	10357	3922	2475	1242	840
2001	374563	235802	106731	178647	38112	26671	10734	5877	6448	5904	2140	1378	1094
2002	218825	213116	134136	60554	101401	21361	14938	6021	3276	3583	3351	1179	1356
2003	1347140	124260	120970	76074	34228	57401	11974	8979	3508	1879	2098	1985	1462
2004	1634880	754275	69566	67644	42499	19051	32040	7303	5496	2111	1115	1281	2105
2005	500326	887251	409330	37726	36622	22977	10228	19934	4485	3359	1233	640	2019
2006	464545	279266	495228	228427	21018	20343	12714	6157	12090	2657	1996	717	1555
2007	291123	271658	163311	289564	133481	12221	11746	7279	3464	6910	1455	1116	1182
2008	328273	179632	167613	100729	178611	82275	7456	6218	3820	1787	3665	715	1149
2009	324474	209421	114595	106924	64251	113913	52440	3622	3017	1852	853	1768	881
2010	626214	203739	131485	71943	67108	40300	71476	25387	1733	1439	880	408	1274
2011	513185	376700	122546	79088	43254	40342	24214	36022	12748	857	702	427	798
2012	487549	295615	216982	70584	45538	24885	23179	12097	18008	6368	422	347	606
2013	572690	272604	165287	121312	39453	25445	13887	11206	5844	8703	3076	200	454
2014	670169	314567	149735	90782	66626	21661	13963	6503	5245	2736	4074	1439	305
2015	528392	366692	172117	81918	49662	36451	11844	6437	2997	2419	1260	1880	804

FIGURES

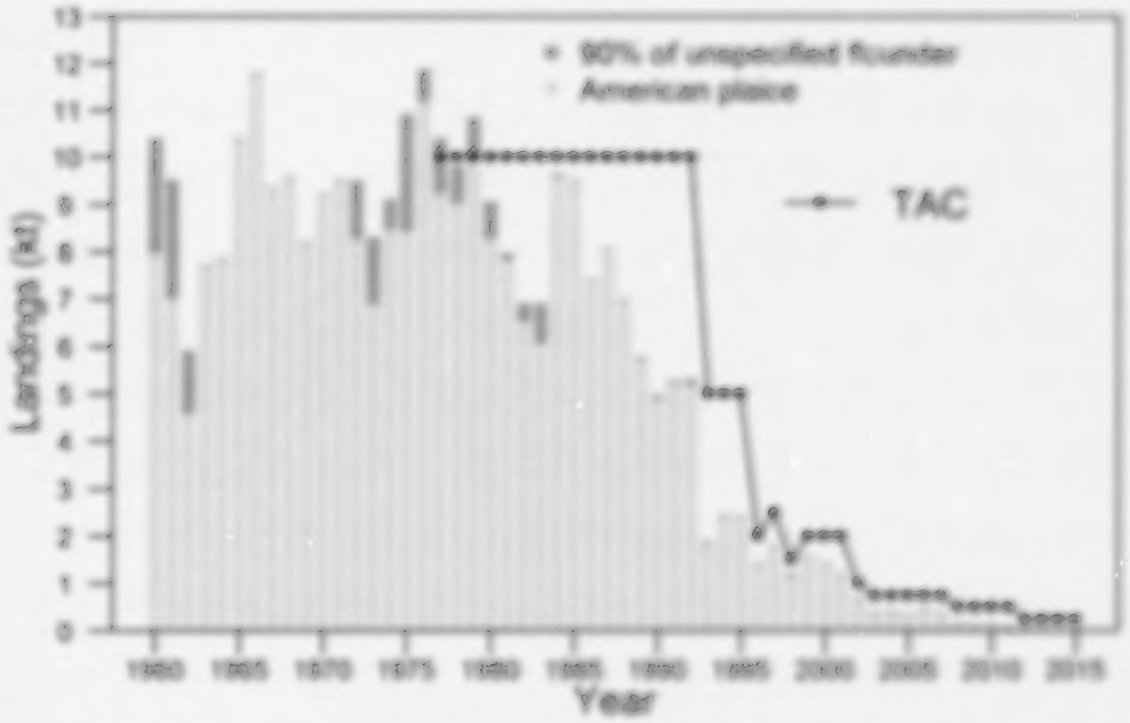


Figure 1. Reported annual landings of 4T American plaice and total allowable catch (TAC), 1960 to 2015. The landings estimates include at-sea discards during the 1970s and 1980s as well as 60% of landings marked as "unspecified flounder".

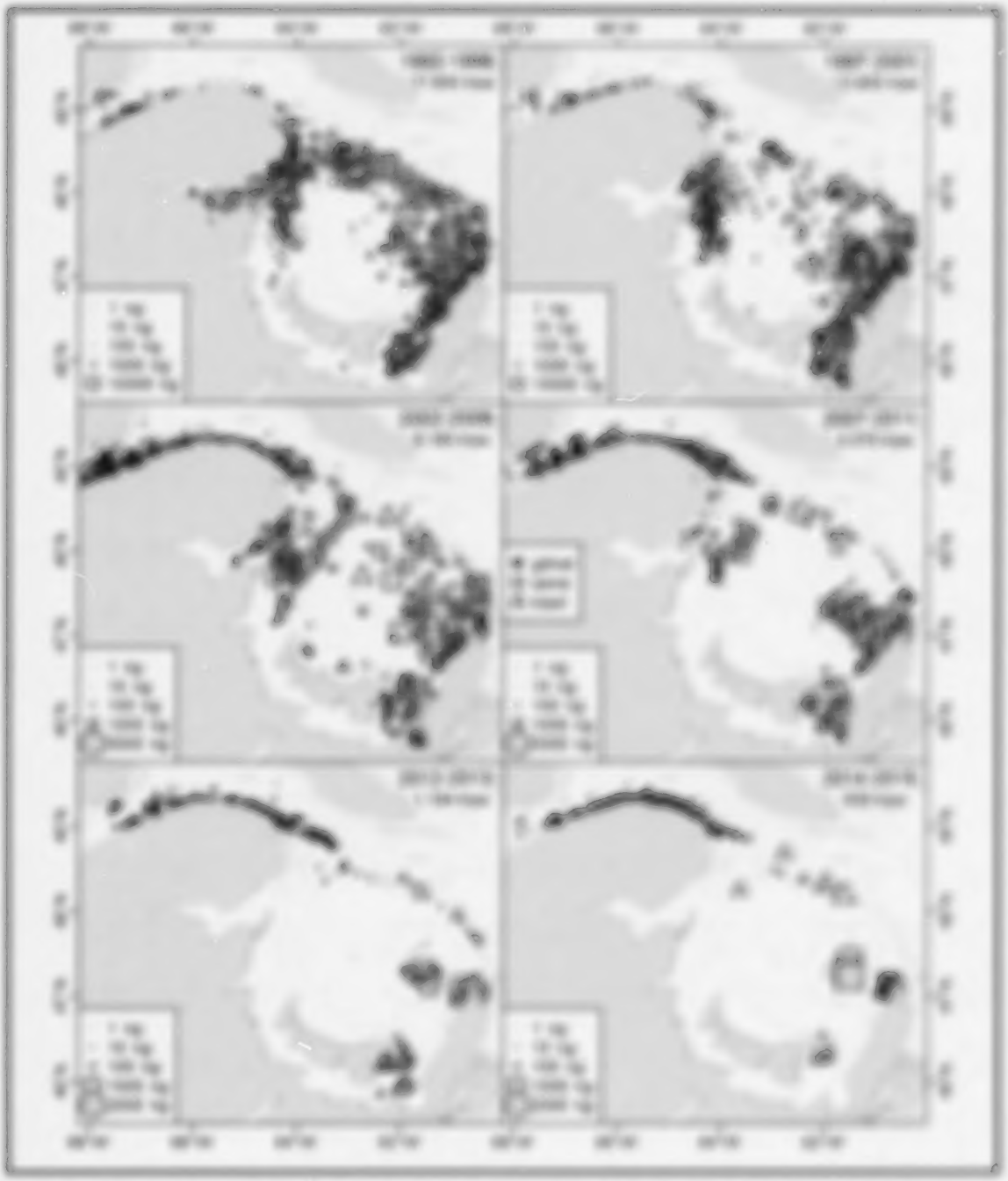


Figure 3. Geographic location of catches of American plaice by gear type in NAFO Div. 4T from 1958 to 2015. Catch locations are shown by 5-year blocks from 1982 to 2011 and by 3-year blocks from 2012 to 2015.

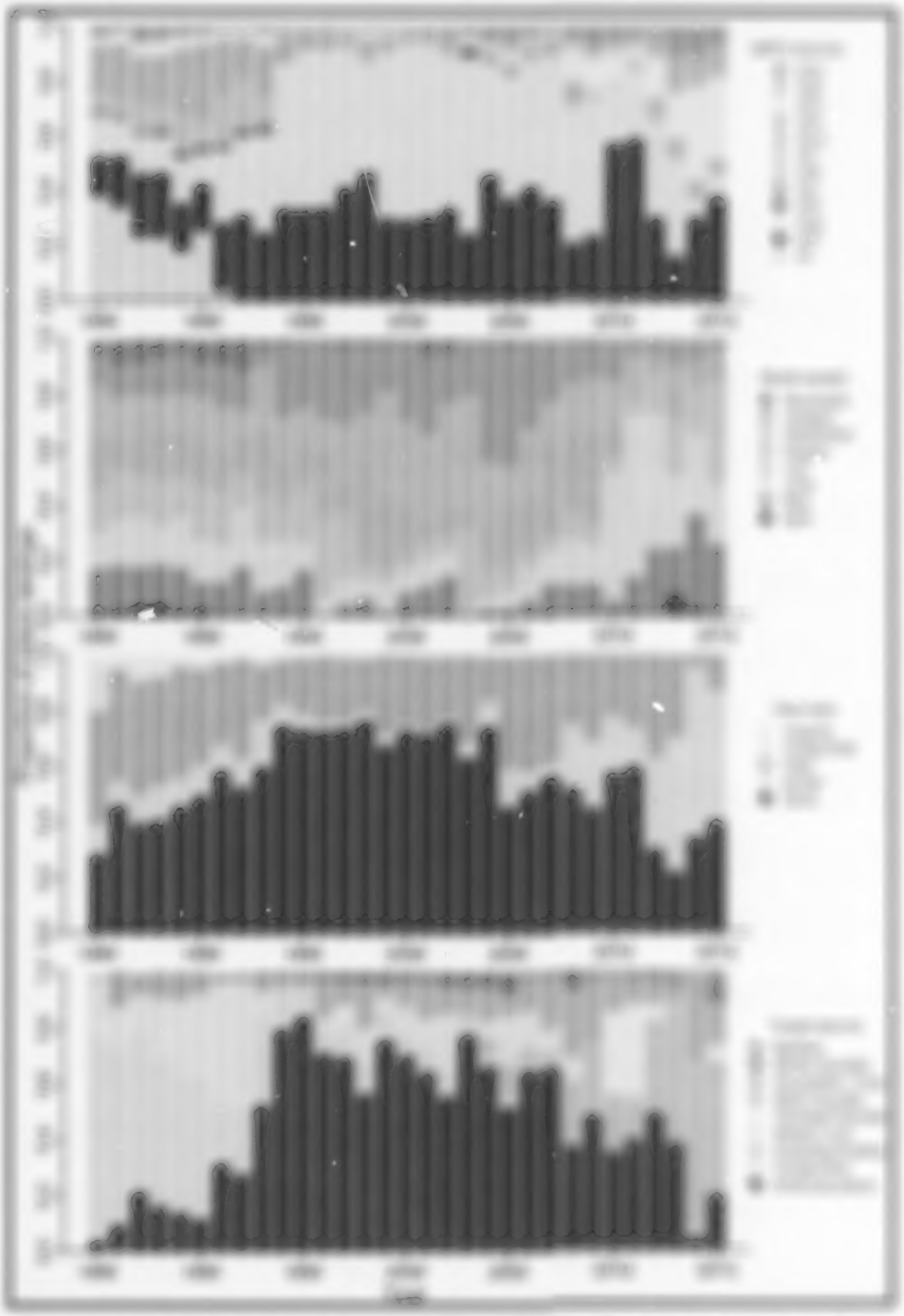


Figure 3. Proportion of annual American plaice landings by GMFS VI[1] subdivision (top panel), by month (second panel), by type of fishing gear (third panel) and by vessel size/power class (bottom panel), 1995 to 2015.

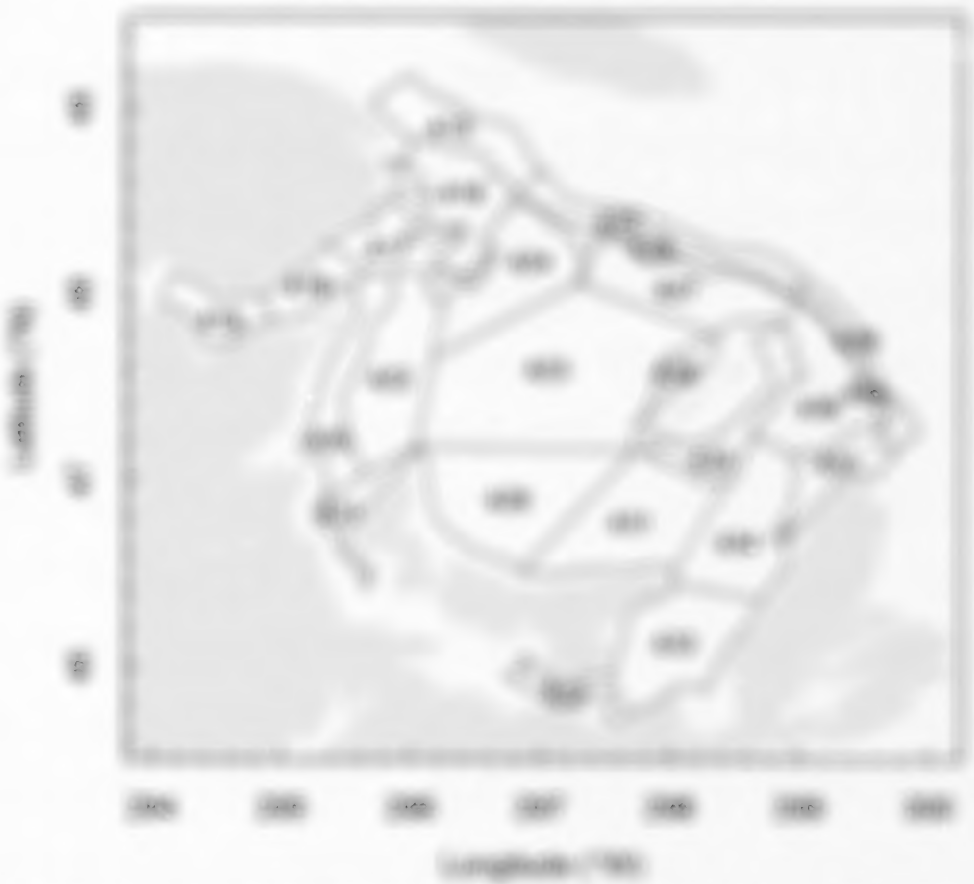


Figure 4 - Map of the Southern Gulf of St. Lawrence showing the study boundaries used during the annual DFO Pelagic Hydroacoustic bottom trawl survey. Three complete bank-to-bottom water column profiles (1 - 1995 (June); 2 - 1996 (June); 3 - 1996 (July)) were collected from the analyzed grid cells and are shown on this map.

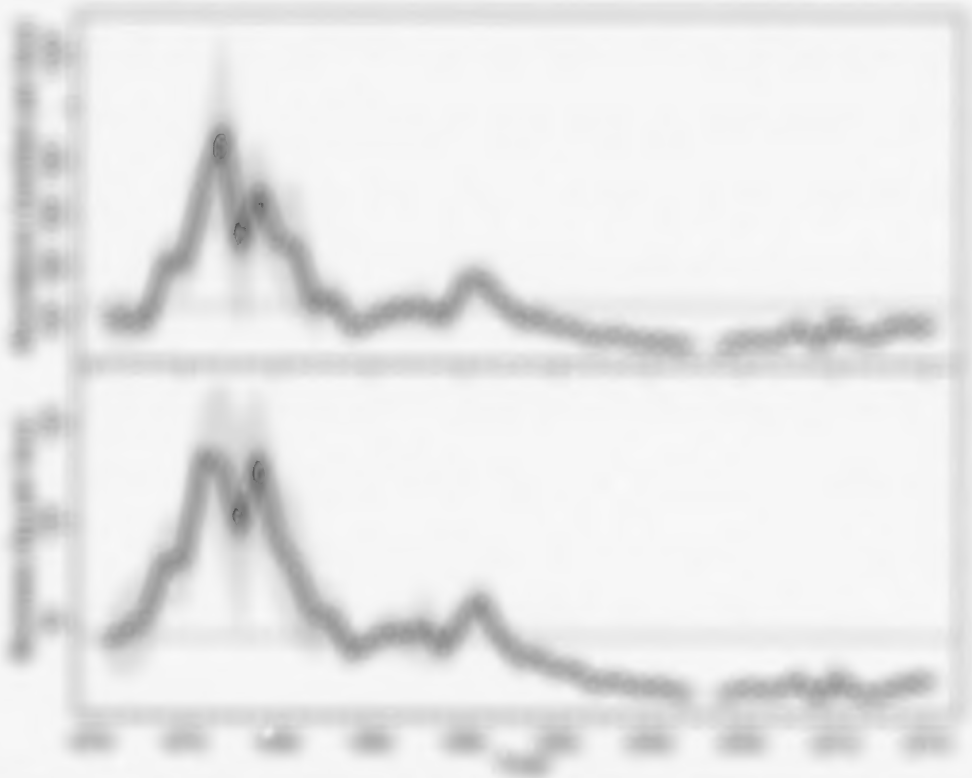
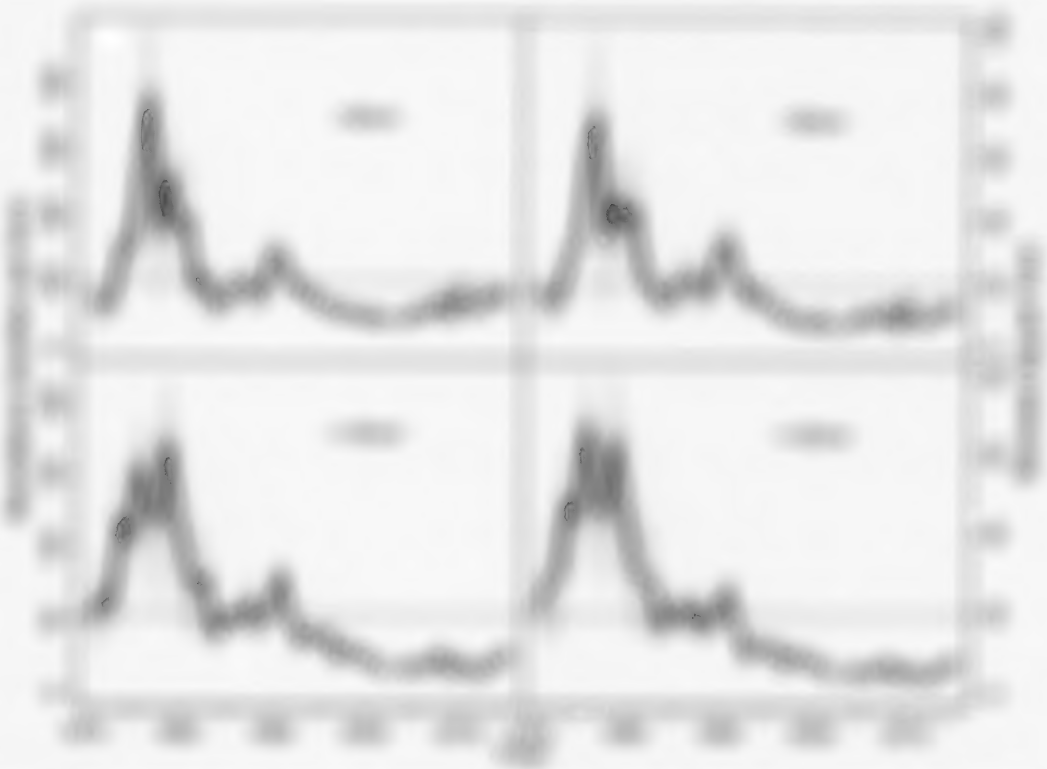


Figure 4.1. Survey abundance and biomass indices of pelagic key prey. Modified trawl survey age 0 key prey (Pacific herring and capelin) abundance (A) and biomass (B) indices (log scale) with 95% confidence intervals. Shaded areas indicate periods of low survey coverage (1982–1983, 1985–1987, 1989–1990, 1992–1994, 1996–1997, 1999–2000, 2002–2003, 2005–2006, 2008–2009, 2011–2012, 2014–2015). Red dashed line in the modified survey mean indicates period of high uncertainty due to low survey coverage.



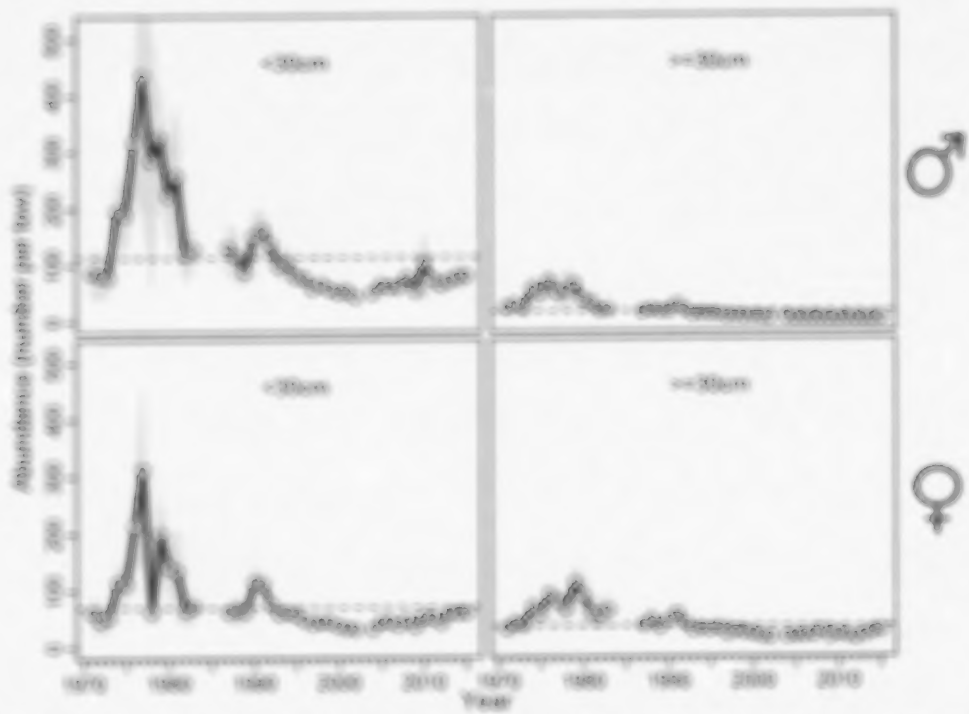


Figure 7. Survey abundance index of male and female plaice of length less than and greater than 30 cm, shown as the stratified mean number per tow, with horizontal line indicating mean of values obtained from 1971 to 2013. No estimates were available for 1984, 1985 and 1986 because no sex determination took place in those years. Data from 2003 is omitted from the figure as an uncalibrated vessel in that year. The black line is the stratified random mean estimate and the shading encompasses the 95% credibility interval of the estimates.

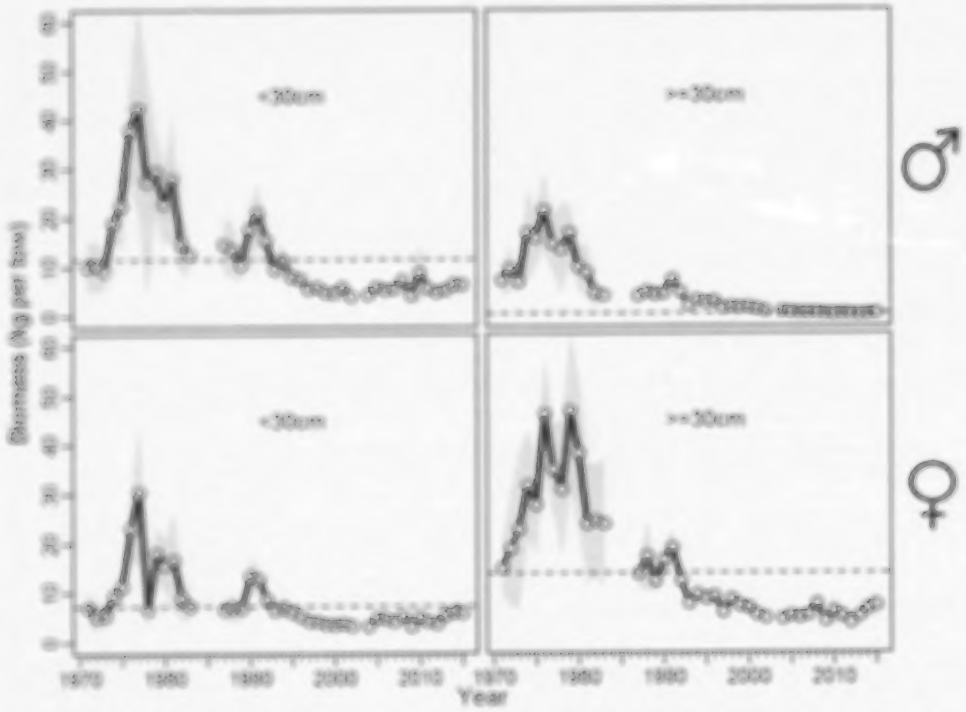


Figure 8. Survey biomass index of male and female plaice of length less than and greater than 30 cm, shown as the stratified mean kilogram per tow, with horizontal line indicating mean of values obtained from 1971 to 2015. No estimates were available for 1984, 1985 and 1986 because no sex determination took place in those years. Data from 2003 is omitted from the figure as an uncalibrated vessel in that year. The black line is the stratified random mean estimate and the shading encompasses the 95% credibility interval of the estimates.

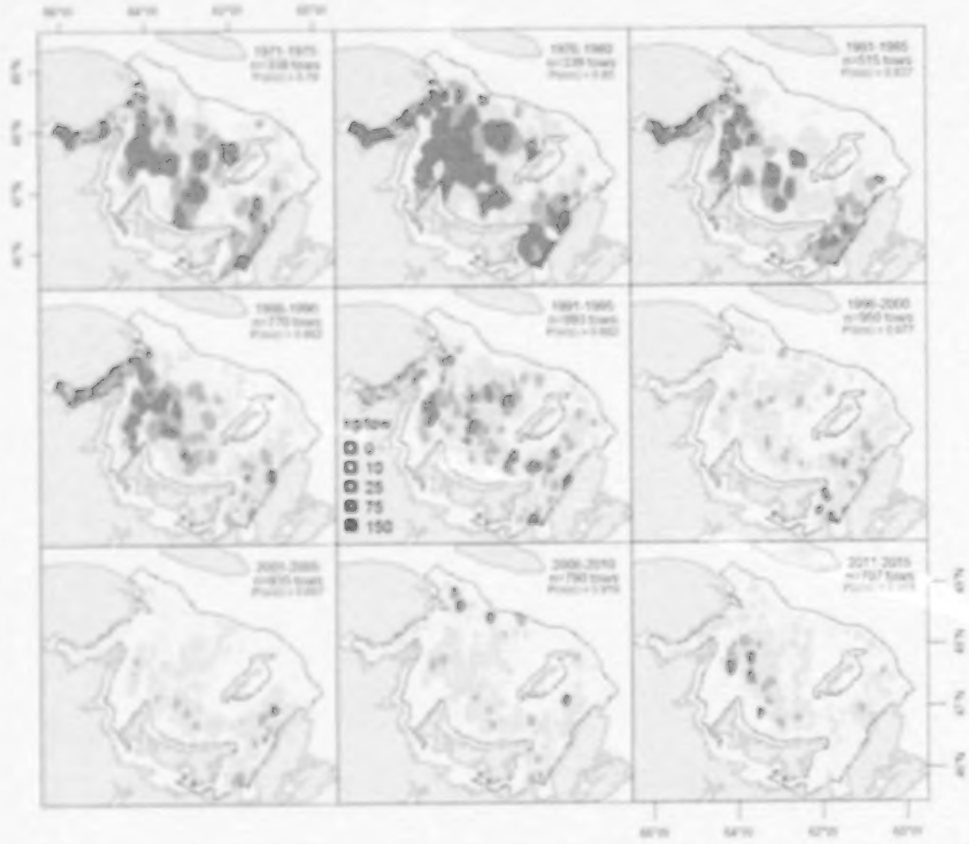


Figure 9. Distribution maps of American plaice catch biomass in the annual Southern Gulf of St. Lawrence trawl survey by 5-year periods.

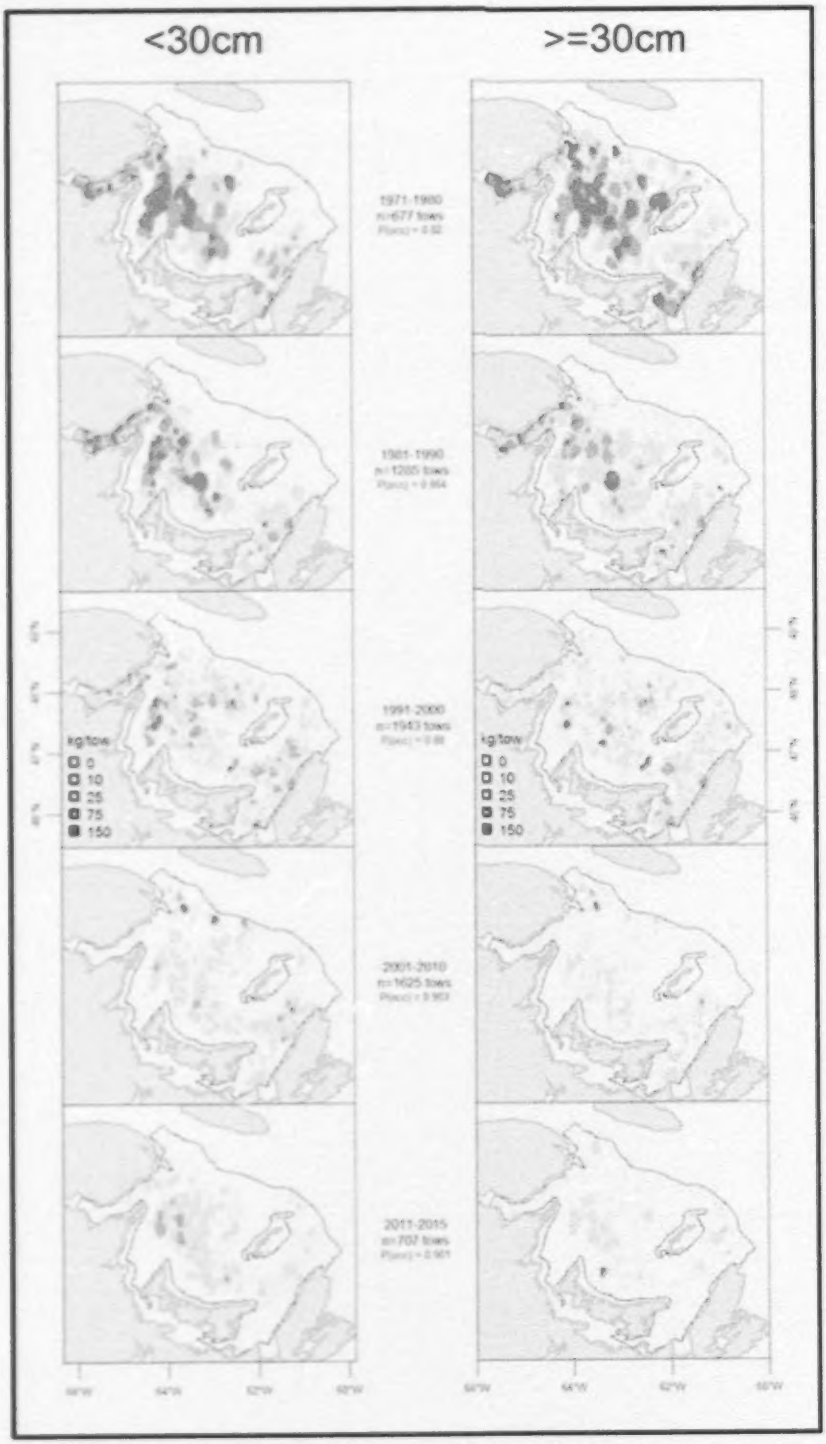


Figure 10. Distribution maps of American plaice catch biomass (individuals smaller than 30 cm in the left panel and individuals greater than 30 cm in the right panel) in the annual Southern Gulf of St. Lawrence trawl survey by 10-year periods (first 4 rows, 1971 to 2010) and 5-year period (last row, 2011-2015).

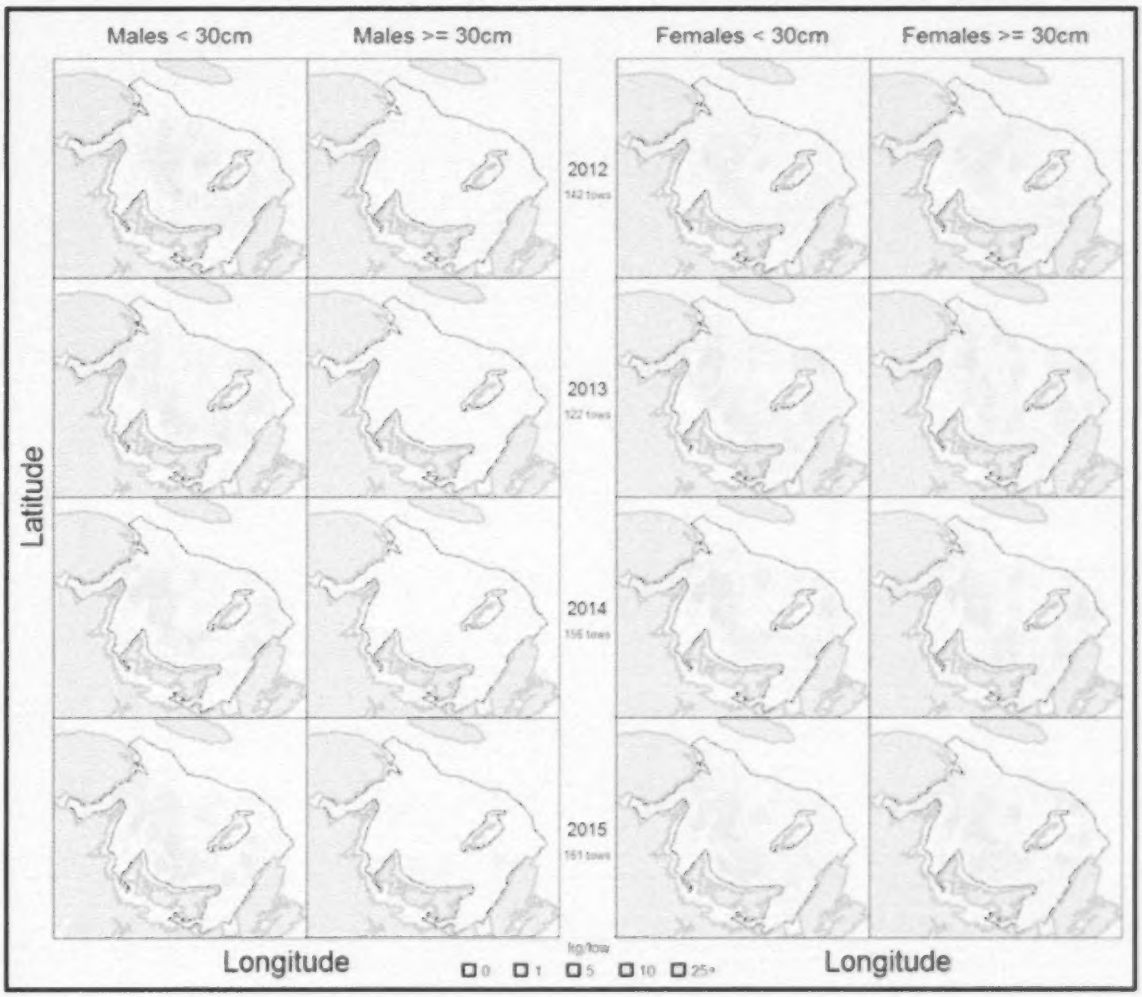


Figure 11. Distribution maps of American plaice catch biomass (kg per tow) in the annual Southern Gulf of St. Lawrence trawl survey over the last four years. Distribution maps for males appear in the two left columns and those for females appear in the two right columns. For each sex, the distribution of individuals smaller than 30 cm appear on the left and that of individuals greater than or equal to 30 cm appear on the right.

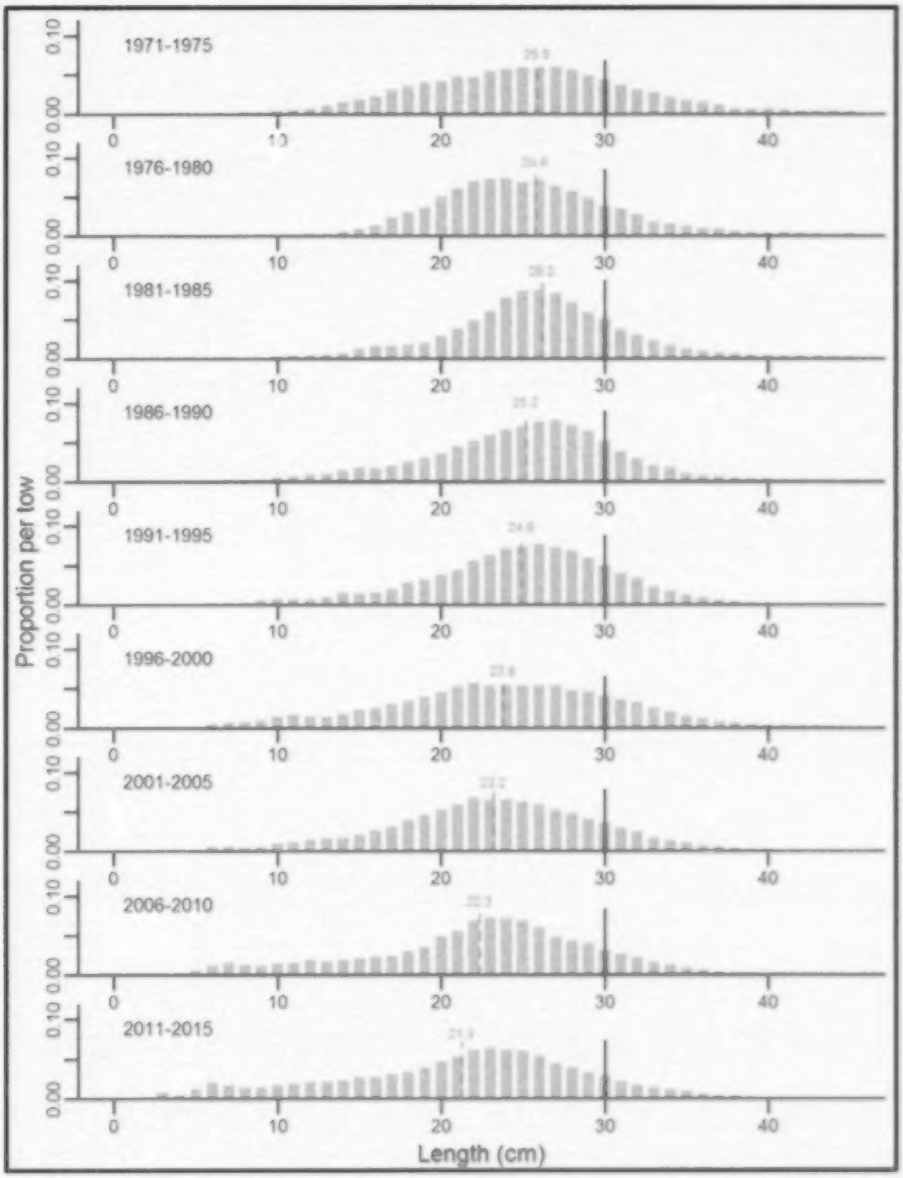


Figure 12. Length frequency of American plaice in the annual Southern Gulf of St. Lawrence trawl survey by 5-year periods. The mean length is shown as the red dashed vertical line and the solid line is the 30 cm minimum commercial size.

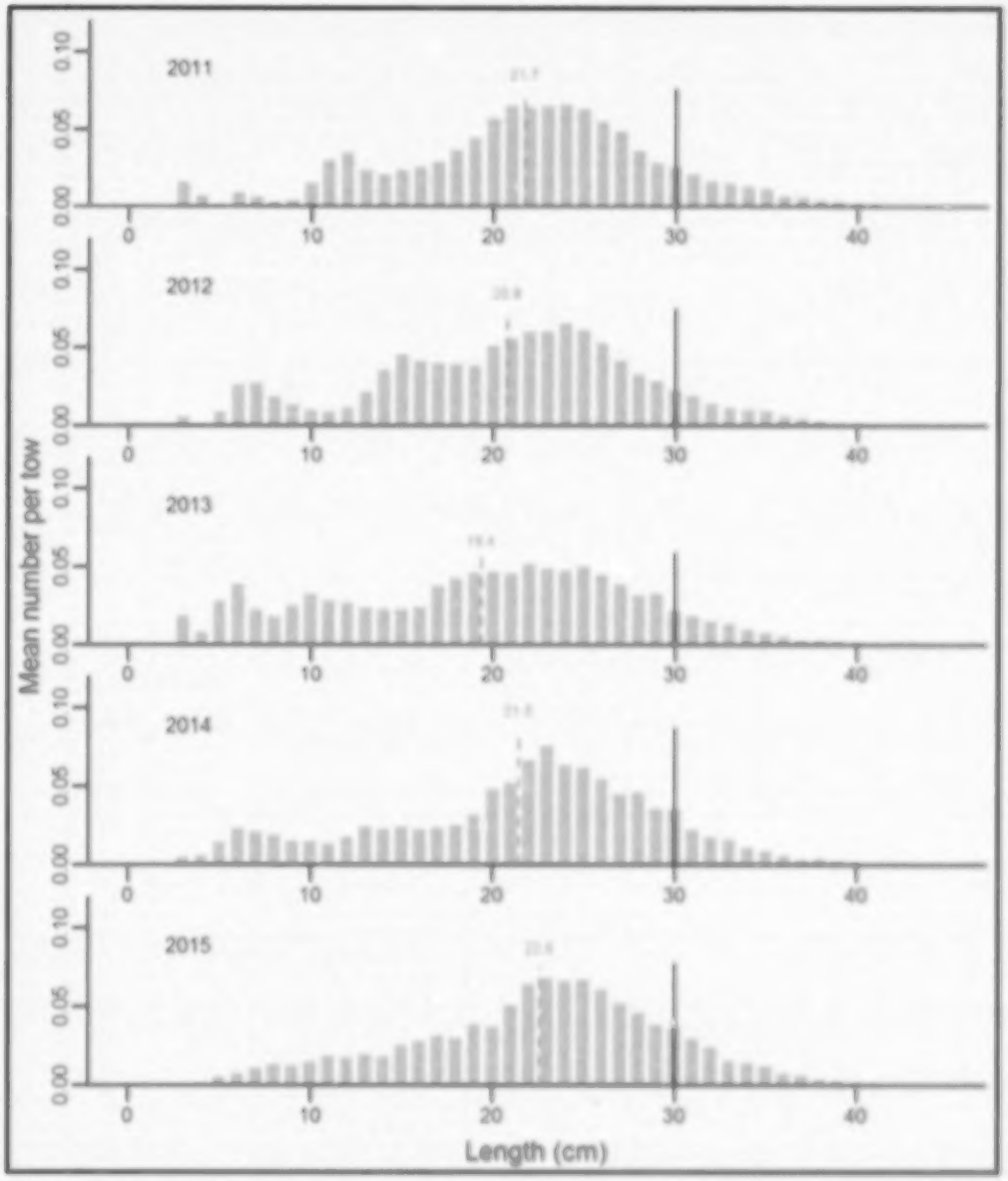


Figure 13. Length frequency of American plaice in the annual Southern Gulf of St. Lawrence trawl survey for the last available 5 years. The mean length is shown as the red dashed vertical line and the solid line is the 30 cm minimum commercial size.

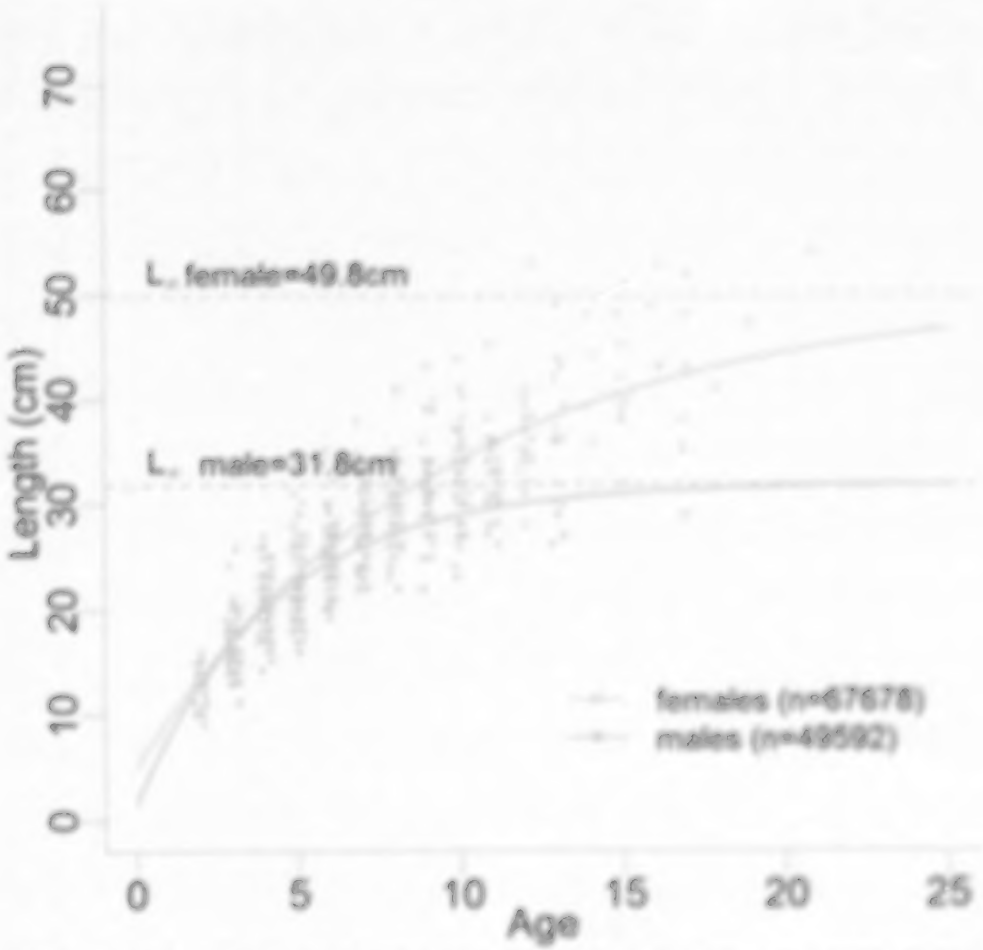


Figure 14. Growth of American plaice showing the relationship between length and age for individuals collected during the annual Southern Gulf of St. Lawrence trawl survey. A von Bertalanffy growth model was fitted separately for males and females. The points on the figure are 300 random age-length observations for each sex, the solid lines are the predicted lengths at age from the fitted growth models and the horizontal dashed lines are the asymptotic lengths for each sex. The age-length observations are jittered to ease visualisation.

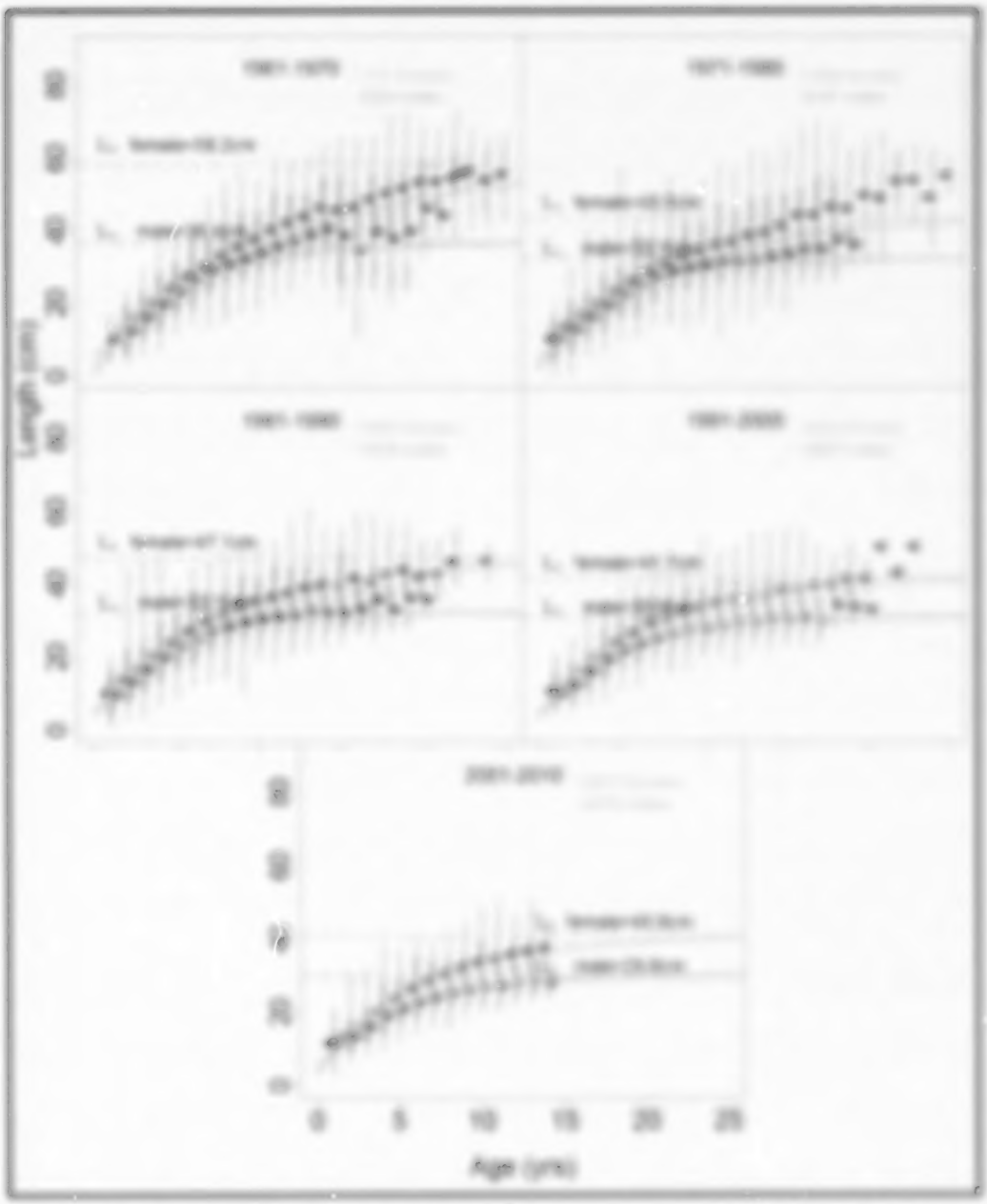


Figure 15. Growth of American plaice showing the relationship between length and age for individuals collected during the annual Southern Gulf of St. Lawrence trawl survey. A von Bertalanffy growth model was fitted separately for males and females born in the same year (cohort year) for different time-domain periods.

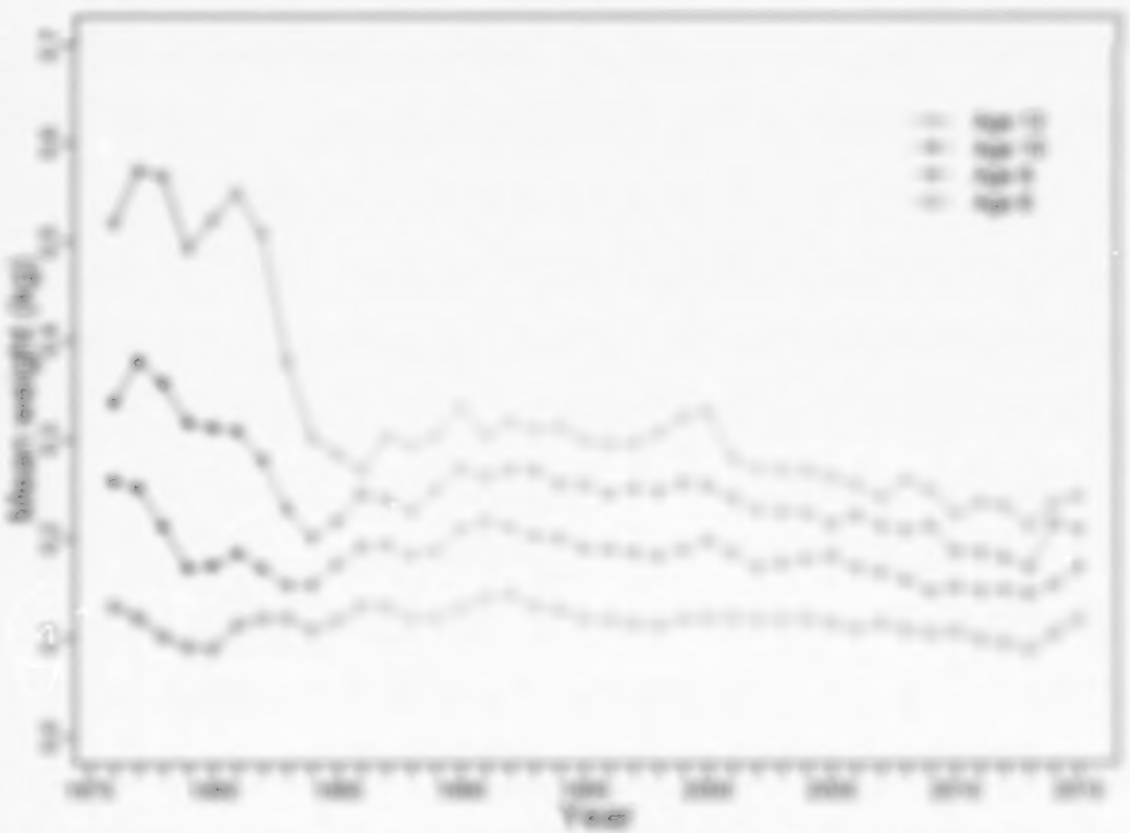


Figure 16. Mean weight-at-age (kg) of American plaice (sexes combined) for ages 6, 8, 10 and 12 years, sampled from the annual southern Gulf of St. Lawrence September research vessel survey, 1978 to 2015.

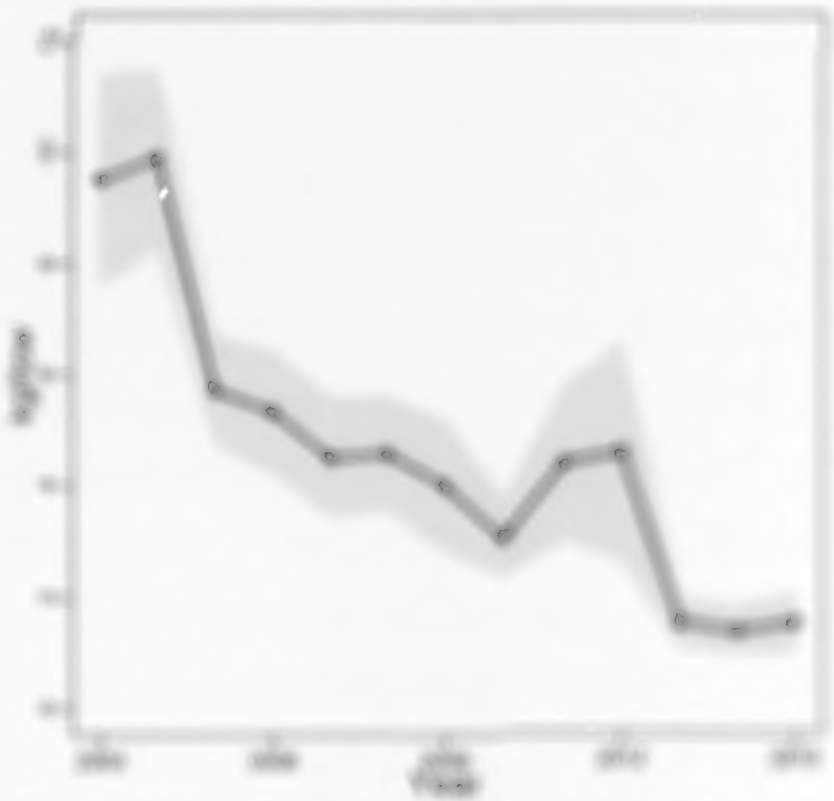


Figure 17. Middle sentinel survey index (log-par mus by Grayling) (2003-2019) for southern Gulf of St Lawrence, 2003 to 2019. The black line is the simplified loess estimate and the shading encompasses the 95% credibility interval of the estimates.

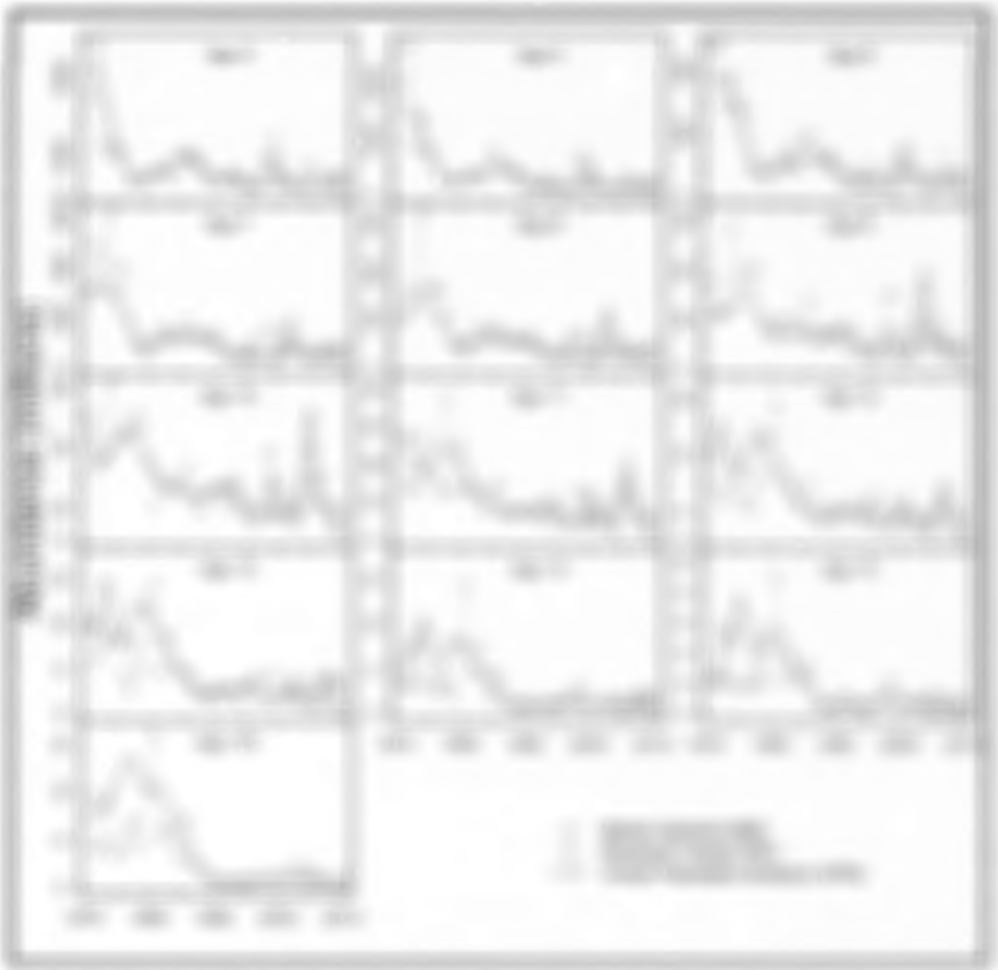
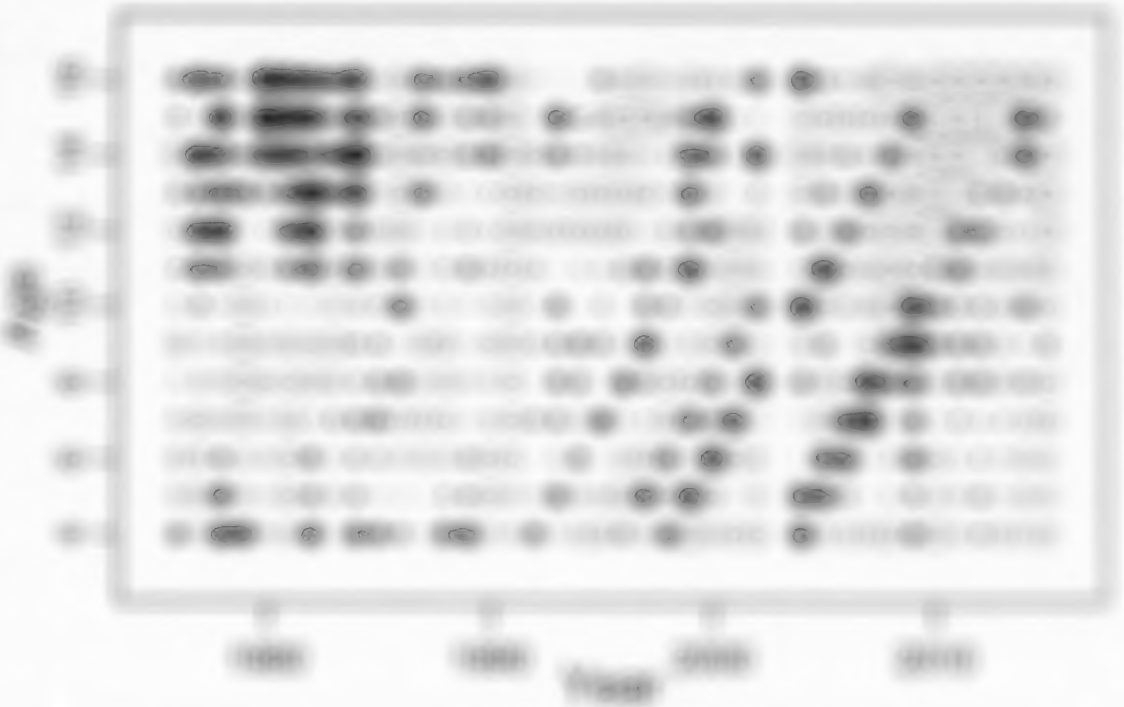
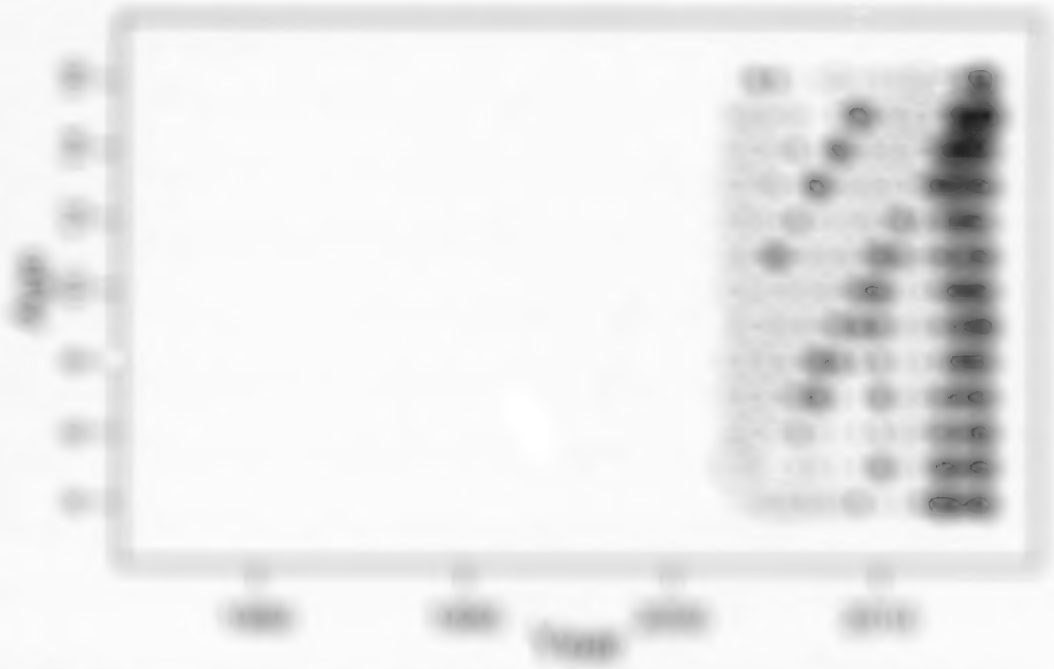


Figure 1. A comparison of population estimates for ages 2 to 10+ for yellowtail rockfish from the 2003 model and those from the survey population estimates in numbers. Estimates for approximately 95% survey error are shown with bars and 95% survey error confidence with grey triangles.


Time


Year

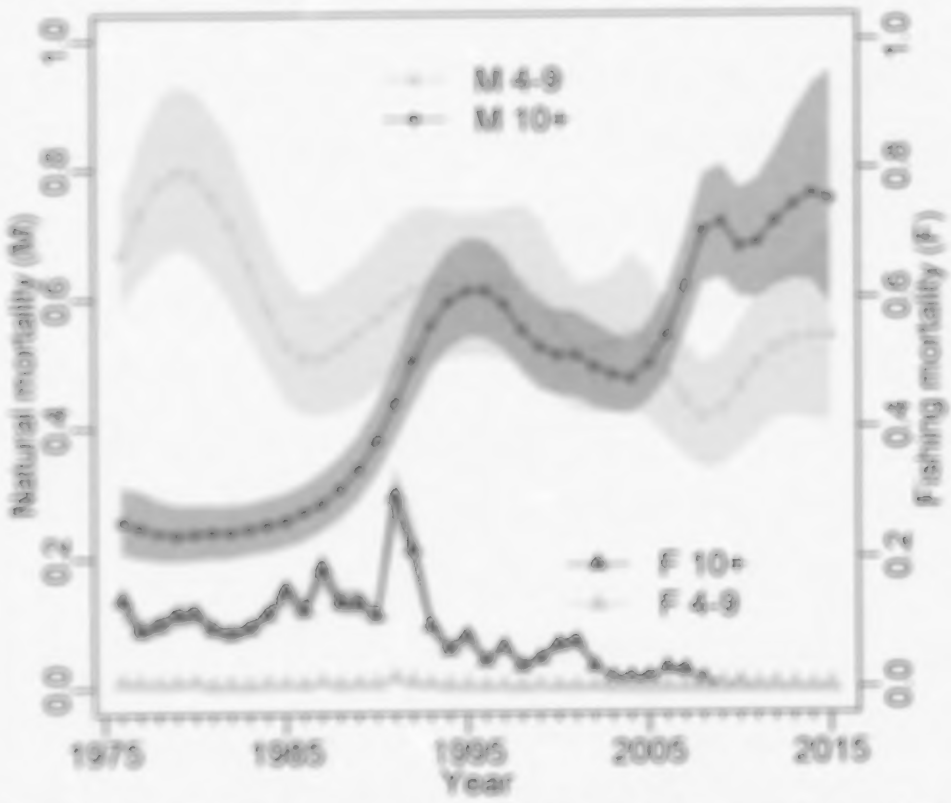


Figure 21. VPA estimates of the instantaneous rates of natural and fishing mortality for ages 4-9 and ages 10+. The solid lines and symbols are the median and the shading encompasses the 95% credibility interval of the estimates.

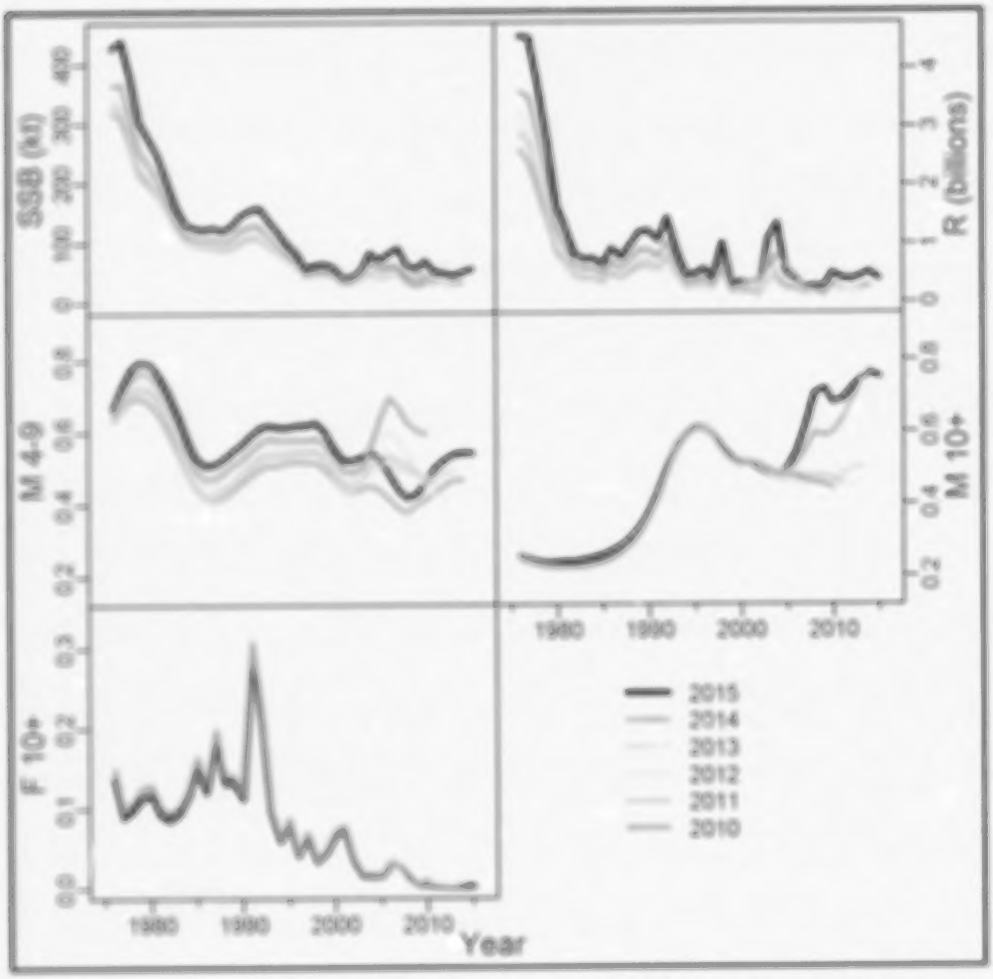


Figure 22. Retrospective analysis of population numbers from VPA showing estimates of spawning stock biomass (SSB, top left panel), recruitment (R, top right panel), natural mortality on ages 4-9 (M 4-9, middle left panel), natural mortality on ages 10+ (M 10+, middle right panel) and fishing mortality on ages 10+ (F 10+ bottom left panel) obtained from the full model and with one to five of the last years of data removed.

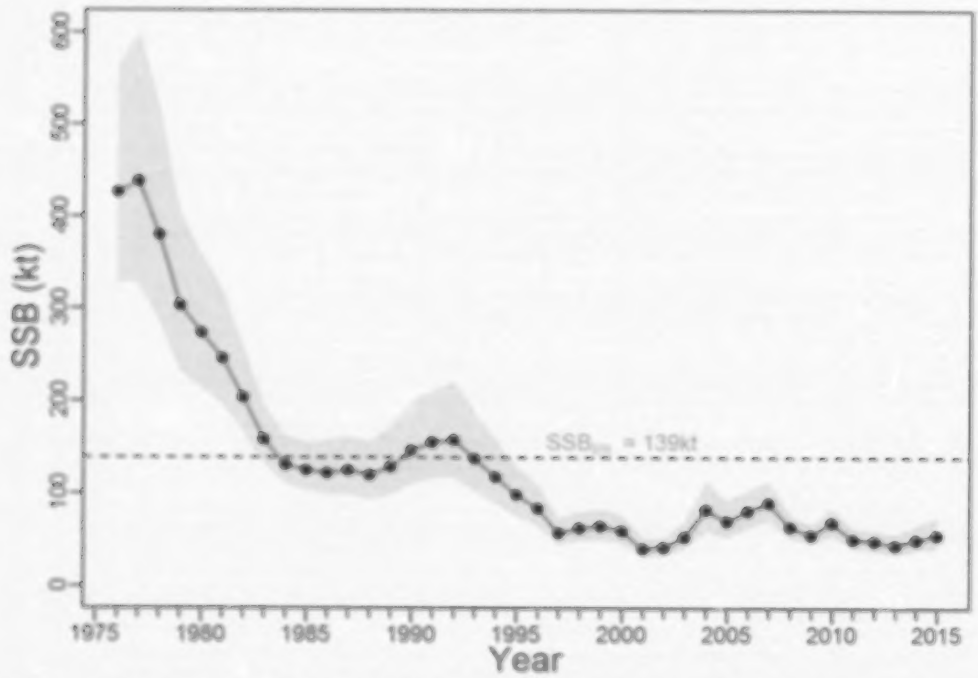


Figure 23. Estimates of yearly spawning stock biomass (SSB) from the virtual population analysis. The horizontal dashed line shows the lower limit reference point (B_{lim}) of 139 kt. The black line is the median and the shading encompasses the 95% credibility interval of the estimates.

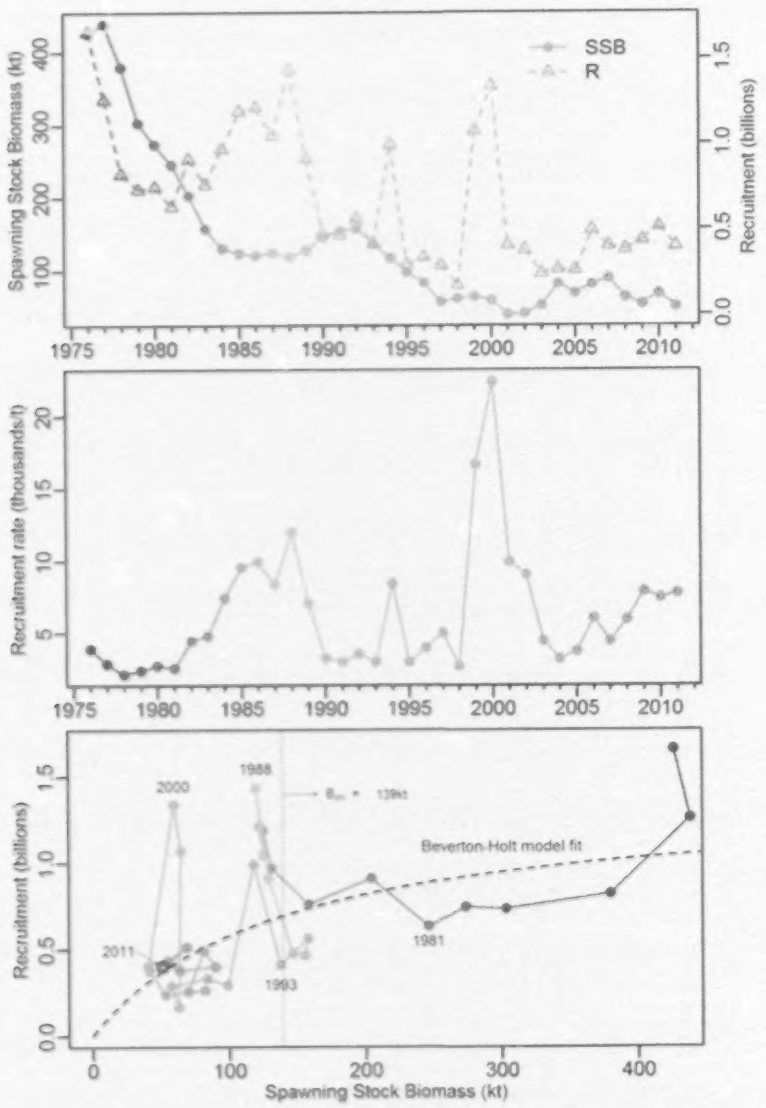


Figure 24. Stock and recruitment estimates from the VPA model. The top panel shows the time-series of spawning stock biomass and recruitment. The recruitment time-series is lagged to match the spawning stock that produced it (i.e., the age of recruitment). The time-series of recruitment rate, expressed as the number of recruits per unit of spawning stock biomass appears in the middle panel. The relationship between spawning stock and recruitment appears in the bottom panel. In all cases, the years are colour code from blue (early years) to red (recent years).

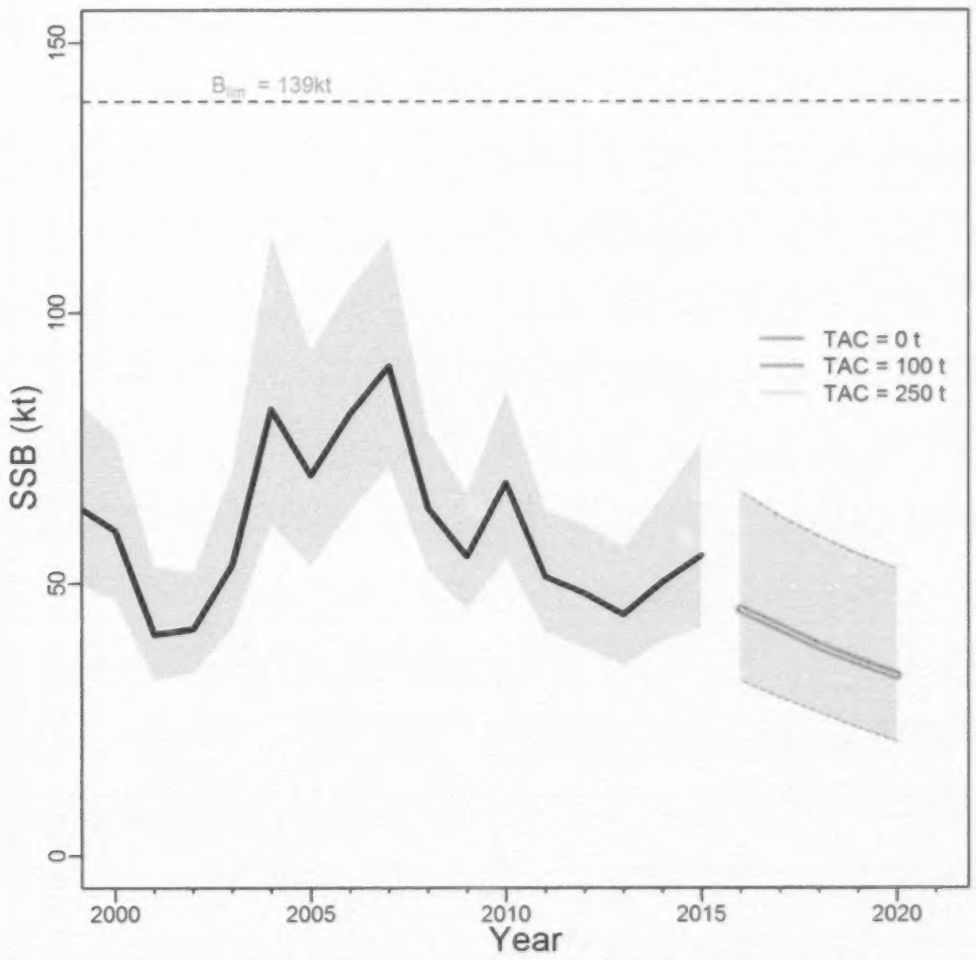


Figure 25. Ten-year stock projections of spawning stock biomass (SSB) under a TAC of 0 t, 100 t and 250 t under current levels of natural mortality. Note that the x-axis starts in year 2000 and that the y-axis has a smaller range that on previous figures showing estimates from 1976 to 2015. The black line is the median and the shading encompasses the 95% credibility interval of the estimates.